Poultry Waste Generation and Land Application in the Illinois River Watershed and Phosphorus Loads to the Illinois River Watershed Streams and Rivers and Lake Tenkiller

Expert Report of Dr. B. Engel

For
State of Oklahoma
In Case No. 05-CU-329-GKF-SAJ

State of Oklahoma v. Tyson Foods, et al.
(In the United States District Court for the Northern District of Oklahoma)

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EXHIBIT
"B"

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Table of Contents

Appendices

List of Figures

List of Tables

1. Executive Summary/Conclusions

Illinois River Studies

Numerous studies have explored phosphorus (P) loads in the Illinois River Watershed (IRW) to the streams and rivers within the watershed and to Lake Tenkiller. Observed data and models indicate nonpoint source pollution is the major contributor to P within the streams and rivers of the IRW and to Lake Tenkiller. Poultry waste application within the IRW to pastures is identified as a substantial contributor to overall P loads within IRW streams and rivers and Lake Tenkiller.

Poultry Waste and P Generation

Each of the defendants' poultry operations within the Illinois River Watershed (IRW) produces a substantial amount of poultry waste and phosphorus. Poultry waste produced within the IRW range between 354,000 and more than 500,000 tons annually. Phosphorus content of the poultry waste ranges from 8.7 million to nearly 10 million pounds annually.

Poultry Waste Land Application

Common practice for poultry waste disposal is land application to pasture and cropped areas. A substantial amount of the defendants' poultry waste and P is land applied within the IRW annually. The poultry waste is applied during the rainy season from late winter through spring.

Observed P Loads in the Illinois River Watershed

The P loads to Lake Tenkiller averaged approximately 505,000 lbs annually between 1997 and 2006. This represents a significant P load to the lake and is much greater per unit area than for other watersheds the region.

Point Sources of P in the Illinois River Watershed

A portion of the P in the IRW reaching Lake Tenkiller is from Waste Water Treatment Plant (WWTP) discharges. P discharges from IRW WWTP have changed over time peaking at slightly more than 204,000 lbs annually in the late 1990s and early 2000s. Beginning in 2003, WWTP P discharges decreased to a little more than 90,000 lbs annually in the IRW due to changes in WWTP technology. The defendants' processing facilities discharge a significant amount of P to WWTPs and thus contribute to point P sources within the IRW.

Phosphorus Mass Balance

A P mass balance for the Illinois River Watershed indicates poultry production is a substantial contributor to P within the Illinois River Watershed. Poultry production within the Illinois River Watershed is currently responsible for more than 76% of P movement into the watershed.

P Loads in the IRW Based on Continued Poultry Waste Land Application

Average annual P loads to water in the Illinois River Watershed attributable to poultry waste application to pastures is calculated at between 432,000 lb to nearly 500,000 lb annually based on poultry P application to the landscape and literature P loss coefficients.

Poultry House Density Correlated to Elevated P Levels in Runoff and Base Flow
The analyses of observed P in runoff and in baseflow for 14 small watersheds within the Illinois River Watershed that were sampled in 2005 and 2006 show a strong and statistically significant correlation between P in runoff and in baseflow and poultry house density. Sub-basin poultry house densities are strong predictors of stream total phosphorus concentration showing a cause and effect relationship between poultry house operations and phosphorus concentrations in IRW waters. From these analyses, it is evident that poultry waste is a substantial contributor to P in stream runoff and in the baseflow within streams of the Illinois River Watershed.

Hydrologic/Water Quality Modeling of Illinois River Watershed

1. The hydrologic/water quality model was able to accurately model the P loads to IRW rivers and streams and Lake Tenkiller.
2. For continued poultry waste application in the IRW at current levels, modeled P loads to Lake Tenkiller would increase during the first 30 years. For the next 70 years, P loads to Lake Tenkiller would decline slightly and stabilize at levels above current Lake Tenkiller P loads due to P saturation of soils.
3. Cessation of poultry waste application in the IRW would decrease P loads to Lake Tenkiller. The reductions in P loads to Lake Tenkiller due to poultry waste land application cessation would be limited to 16% during the first 10 years following cessation due to continued P load contributions from historical poultry waste application in the IRW that have elevated soil P. Following poultry waste land application cessation in the IRW, reductions in P loads to Lake Tenkiller would reach 50% by years 51-60.
4. For continued growth in the IRW poultry industry at a rate the same as that between 1982 and 2002, P loads to Lake Tenkiller would increase substantially. Within 40-50 years, P loads to Lake Tenkiller would nearly double (increase of 92%).
5. The addition of vegetated 100 foot buffers along all 3rd order and larger IRW streams combined with poultry waste application cessation in the IRW would provide further reductions of P loads of between 3 and 5% compared to poultry waste application cessation alone. The addition of vegetated 100 foot buffers along all IRW streams combined with poultry waste application cessation in the IRW would provide further reductions of P loads of between 10 and 13% compared to poultry waste application cessation alone.
6. P loads to Lake Tenkiller would be more than 275,000 lbs less than current levels (less than ½ of current levels) if poultry waste had never been disposed of in the IRW. It would take approximately 100 years of cessation of poultry waste application to return P loads in the IRW to what they would have been if no poultry waste land application had occurred.
7. P loads to Lake Tenkiller since 1954 have increased at approximately 10,000 lbs per year. Poultry waste application in the IRW is responsible for approximately 6,600 lbs of this increase each year.
8. Poultry waste land application in the IRW is a substantial contributor (45% between 1998 and 2006 and 59% between 2003 and 2006) to P loads to Lake Tenkiller, representing the largest P source. WWTP P loads are the second largest contributor to P loads to Lake Tenkiller. Poultry plant discharges to WWTP represent a significant portion of WWTP P loads.

9. Cattle in the IRW recycle P brought into the IRW to feed poultry that is excreted by poultry and land applied to pastures within the IRW. Although the P contribution of cattle is from poultry waste, cattle accelerate the movement of P into IRW streams and rivers when they excrete waste in and near IRW streams. Six percent of P loads to Lake Tenkiller result from cattle in and near IRW streams.
10. The contributions of septic systems to P loads in the IRW are negligible.

Additional data from the IRW continue to become available. These data will be used to refine analyses reported herein and in new analyses as appropriate. Therefore, I reserve the right to update this report.

2. Review of Illinois River Watershed Studies - P Contribution

Numerous studies have explored P loads in the Illinois River Watershed (IRW) to the streams and rivers within the watershed and to Lake Tenkiller. ***Analysis of these reports indicates that poultry waste application to pastures within the watershed is a substantial contributor to P in the streams and rivers of the watershed and to Lake Tenkiller.***

The majority of these studies indicate that P in the streams and rivers within the IRW has increased over time. These studies consistently conclude that nonpoint sources of P are a substantial contributor to total overall P loads to the Illinois River, its tributaries, and Lake Tenkiller. When these studies identified the source of nonpoint source P, they consistently identify land application of poultry waste as the primary nonpoint source. Information is summarized from these reports in the remainder of this section.

Observed data and models indicate nonpoint source pollution is the major contributor to P loads within the streams and rivers of the IRW and to Lake Tenkiller. Poultry waste application within the IRW to pastures is identified as the major and a substantial contributor to overall P loads within IRW streams and rivers and Lake Tenkiller.

The USGS (Terry et al., 1984) conducted an extensive water quality study on the Illinois River above Lake Frances from September 1978 to September 1981. The study concluded that existing water quality in the Illinois River, and several tributaries, did not meet the Arkansas State Guideline of 100 ug/l total phosphorus (as P) in streams.

Oklahoma's 305(b) Report (Oklahoma Department of Pollution Control, 1984 as reported by Gade (1998)) included an assessment of trends for certain water quality parameters at USGS gauging stations 07195500 (Illinois River at Watts), 07196000 (Flint Creek near Kansas, OK), 07196500 (Illinois River near Tahlequah), and 07197000 (Baron Fork near Eldon, OK) for the period from 1975 to 1983 done by the Oklahoma Department of Pollution Control (ODPC). The report concluded there was an apparent increasing trend in concentrations of total phosphorus at all four stations.

Walker (1987 as reported by Gade (1998)) reviewed EPA's STORET data base and Gakstatter and Katko's data (1986 as reported by Gade (1998)) and concluded that phosphorus concentrations have increased by a factor of roughly two to three over the past decade. Walker used flow-weighted annual mean total P concentrations to develop conclusions about trends. He suggested it would be proper to compare years of comparable flow to determine if total phosphorus concentrations had indeed increased. Walker also concluded the most probable cause for accelerated eutrophication in Lake Tenkiller is increased point source nutrient loadings since nonpoint sources tend to be rich in nitrogen while point sources tend to be rich in phosphorus (Walker, 1987 as reported by Gade (1998)). Walker's interpretation is incorrect because poultry waste contains significant amounts of P that is not in proportion to plant needs. Thus, when poultry waste has been applied to meet the nitrogen needs of plants there is inevitably an excessive P application to pastures in the IRW.

Jobe et al. (1996) recommended a 30-40% reduction in nutrient input into Lake Tenkiller ("Clean-Lakes" Diagnostic and Feasibility Study on Tenkiller Lake, Oklahoma).

The authors of Illinois River Water Quality, Macroinvertebrate and Fish Community Survey explored EPA STORET data. At the Savoy station, total P load increases slightly despite high P peaks in mid 80s. They noted that peak values seem to be in response to increased runoff.

Burks and Kimball (1988 as reported by Gade (1998)) performed a study evaluating existing concentrations of nutrients transported by the Illinois River to make an assessment of the potential effects of water quality in Lake Tenkiller. They used QUAL2E (a water quality model) on the lower reaches of the Illinois River above Lake Tenkiller and the upper segment of Lake Tenkiller. They found a projected decrease in P input from Tahlequah's WWTP after construction and implementation of a P removal system would be adequate in reducing the rate of eutrophication in Lake Tenkiller. However, they concluded that other point and non-point sources within the basin would still contribute to the further deterioration of water quality in Lake Tenkiller. They recommended concerted efforts to public and private agencies to reduce P input into Lake Tenkiller to prevent further deterioration.

Harton (1989 as reported by Gade (1998)) performed a modeling study of the Illinois River in an attempt to analyze contributions of point and nonpoint source P loading on Lake Tenkiller. The Fayetteville wastewater treatment plant effluent was determined to have no observable effect on eutrophication in Lake Tenkiller. Harton concluded the substantial distance from the point of entry of the effluent into the Illinois River to Lake Tenkiller was sufficient to allow for nearly total removal by biological activity. Nonpoint Source (NPS) total P loadings from Oklahoma and Arkansas were found to be the main loading sources to the lake. Harton concluded that removal of 70-90% of the total P loading from point and nonpoint sources would be necessary to bring eutrophication under control in Lake Tenkiller.

Burks et al. (1991 as reported by Gade (1998)) evaluated factors affecting water quality in the Illinois River. In-stream total P concentration exceeded the 0.1 mg/l level recommended by the EPA (US EPA, 1986) to prevent enrichment of streams or tributaries to standing bodies of water. They suggested there was "overwhelming evidence" that P loading to the upper end of Lake Tenkiller was excessive, and predicted decreases in water quality for the lake. Total N loading also was shown to be increasing over time. They suggested strict reduction of both point and nonpoint nutrient inputs into the system, and suggested that the focus be placed on P.

The Phase I Diagnostic and Feasibility Study on Tenkiller Lake (OWRB, 1996) found that mean annual concentrations of P, N, and chlorophyll a measured throughout Lake Tenkiller were indicative of eutrophic conditions. Recommendations for control of eutrophication were focused on the reduction of P from both point and nonpoint sources.

Gade (1990 as reported by Gade (1998)) presented temporal trend tests (Kendall Tau) on flow adjusted concentrations of total P at USGS gauging stations 07195500 (Illinois River at Watts, OK), 07196000 (Flint Creek near Kansas, OK), 07196500 (Illinois River near Tahlequah, OK), and 07197000 (Baron Form Creek near Eldon, OK) all indicated highly significant upward trends for the period from 1976 to 1986.

Phillips (2007) summarizes several studies that have been conducted on the IRW and its waters, including Lake Tenkiller, that document excess P in these waters and the source of the excess P. Phillips concludes that poultry waste application to soils in the IRW has contributed to the historical water quality problems within the IRW and Lake Tenkiller.

Nelson et al. (2002) analyzed 5 years of observed P data in the Illinois River at the Arkansas Highway 59 bridge just prior to the Illinois River reaching Oklahoma. TP load at the Illinois River near the Arkansas-Oklahoma border is about 208,000 kg where 45% of the annual loading is from municipal WWTPs (Haggard et al., 2003). Up to 83% of the average annual P loading from municipal WWTPs in the Illinois River can be attributed to a single WWTP (Springdale, Arkansas – see Section 6 of this report for further discussion) (Nelson et al., 2002). However, in 2003 the WWTP loads were decreased significantly such that the total load in the IRW draining to Lake Tenkiller is approximately 90,000 lb annually (compared to 226,000 lb prior to 2003). Haggard and Soerens (2006) indicated that WWTPs in the IRW have recently adopted a 1 mg/L P standard for discharge.

Nelson et al. (2002) also performed a P mass balance for the Arkansas portion of the Illinois River Watershed. They concluded that even if point sources were eliminated, the P concentrations in the Illinois River at the sampling location on Arkansas Highway 59 would exceed the 0.037 mg P standard. Their analyses identify poultry waste spread on pastures as the primary source of the nonpoint source (NPS) P in the Illinois River at Arkansas Highway 59.

Green and Haggard (2001) examined phosphorus and nitrogen concentrations and loads at the Illinois River south of Siloam Springs, Arkansas between 1997 and 1999. They found that flow-weighted nutrient concentrations and nutrient yields at the Illinois River site were about 10 to 100 times greater than national averages for undeveloped basins. Most of the phosphorus load was contributed during surface runoff. On average, base flow contributed 15 percent of the annual total phosphorus load; surface runoff contributed 85 percent of the annual total phosphorus load. On average, 72 percent of the soluble reactive phosphorus annual load was contributed during surface runoff.

Haggard et al. (2002) examined phosphorus concentrations and loads in the State of Oklahoma's scenic rivers (The Baron Fork, Flint Creek, and the Illinois River) between 1998 and 2000. They found that approximately 39% of the 367,000 kg/yr phosphorus load to Lake Tenkiller from the Illinois River and Baron Fork was in the dissolved form, and over 94% of the phosphorus load was transported during surface runoff. Annual phosphorus loads were least in 1999 (232,000 kg/yr) but were greatest in the following year (506,000 kg/yr in 2000). Lake Francis, a small impoundment near the Arkansas-Oklahoma border, retained about 26 % of the phosphorus transported from Arkansas to Oklahoma in the Illinois River. Phosphorus yields (kg/km^2) and flow-weighted concentrations from the IRW were about 10 times greater than values reported for undeveloped basins, nationally and regionally (Haggard et al. (2002)).

Pickup et al. (2003) observed phosphorus concentration for the Illinois River Basin, in Arkansas and Oklahoma between 1997and 2001. These data were used to calculate P loads and yields. Phosphorus concentrations in the Illinois River basin generally were significantly greater in runoff-event samples than in base-flow samples. Loads appeared to generally increase with time during 1997-2001 at all stations, but this increase might be partly attributable to the beginning of runoff-event sampling in the basin in July 1999. Runoff components of the annual total phosphorus load at USGS gauges in the IRW ranged from 58.7 to 96.8% from 1997-2001. Mean flow-weighted concentrations were more than 10 times grater than the median and were consistently greater than the 75th percentile of flow-weighted phosphorus concentrations in samples collected at relatively undeveloped basins of the United States. The annual average phosphorus load entering Lake Tenkiller was about 577,000 pounds per year, and more than 86% of the load was transported to the lake by runoff which is predominately NPS P.

Tortorelli and Pickup (2006) observed phosphorus concentrations in the Illinois River Basin, Arkansas and Oklahoma between 2000-2004. They used this data to compute P loads at IRW USGS gauging stations. Annual total loads in the Illinois River from Watts to Tahlequah increased slightly for the period 2000-2002 and decreased slightly for the periods 2001-2003 and 2002-2004. Calculated mean annual runoff loads ranged from 68-96% of the calculated mean annual total phosphorus loads from 2000-2004. Calculated mean seasonal base-flow loads were generally greatest in spring (March through May) and were least in fall (September through November). Calculated mean seasonal runoff loads generally were greatest in summer (June through August) for the period 2000-2002 but were greatest in winter (December through February) for the period 2001-2003, and greatest in spring for the period 2002-2004. The calculated mean annual phosphorus load entering Lake Tenkiller ranged from about 391,000 pounds per year to 712,000 pounds per year, and from about 83 to 90 percent of the load was transported to the lake by runoff which is predominately NPS P.

The mean load of total P was calculated to be 1180 lbs/day at the upper end of Tenkiller (Harton, 1989 as reported in Burks) of which an estimated 221 lbs/day were point sources with the remainder from nonpoint sources (73%). Nonpoint source P was estimated at 415 lbs from Arkansas and 189 lbs from Oklahoma.

Vieux and Moreda (2003) used observed P concentration data and flow data for the IRW to create a relationship between stream/river flow and P concentrations. Figures 2.1 and 2.2 show P concentrations at Watts and Tahlequah that they plotted. These P concentrations were consistently above the 50 ug/l level that has commonly been recommended as a water quality threshold. They found the majority of P loading in the IRW occurred during direct runoff events and found high concentrations of P at high flow rates and low P concentrations for low flow rates. Vieux and Moreda (2003) also noted that the P generated by the poultry industry in the IRW is equivalent to a human population of 8 million people (2000 population of the IRW is slightly more than 280,000 people). They further indicated that poultry manure is stored and then applied to pastureland. They conclude that, with the large number of poultry in the IRW, the potential for contamination by poultry manure is high. They indicate that most of the P reaching Lake Tenkiller is from NPS sources.

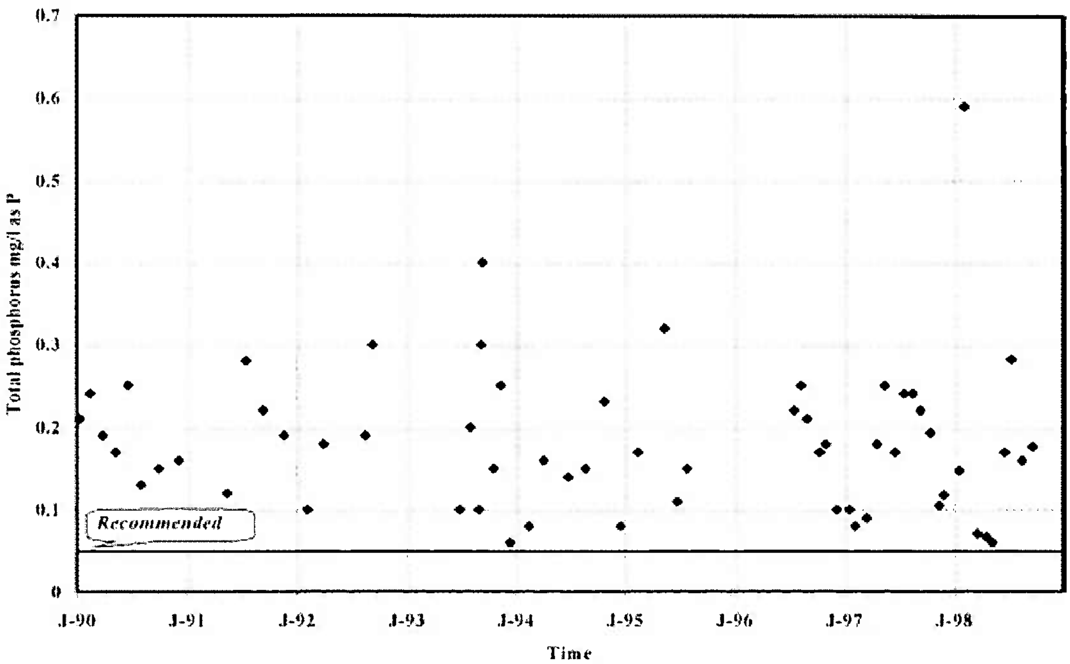


Figure 2.1. Vieux and Moreda (2002) plot of observed P at Watts Station for 1990-1998

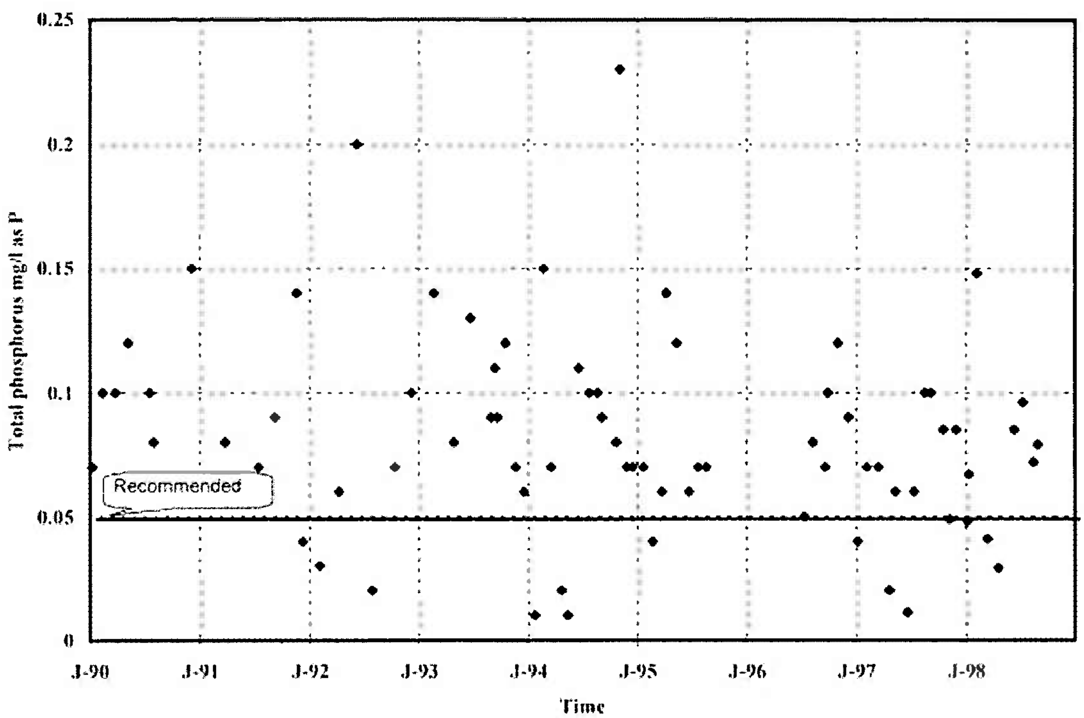


Figure 2.2. Vieux and Moreda (2002) plot of observed P at Tahlequah Station for 1990-1998

Walker (1987) used monitoring data from subwatersheds in the IRW not influenced by Waste Water Treatment Plants (WWTP) and found the average P concentration in runoff due to NPS from Arkansas was .150 mg/l and from Oklahoma was .100 mg/l.

Gade (1998) found statistically significant increasing P concentration at 07194800 (Illinois River near Savoy, AR) and 07197000 (Baron Fork Creek near Eldon, OK) for 1980-1993. Highly significant increasing total P load trends (1980-1993) were found at 07194800, 07196500 (Illinois River near Tahlequah, OK), 07196000 (Flint Creek near Kansas, OK) and 07197000.

Gade (1998) estimated P loads to Lake Tenkiller using a model of the IRW. Gade (1998) indicated that in1985 NRCS data identified 1,246 sites that had poultry houses for a total of 2,692 houses in the IRW. Gade (1998) used poultry house data to estimate P production in poultry waste, pasture applied P and pasture area by Illinois River Basin subwatershed in his modeling. The land application of P was based on house location, soil test phosphorus (STP), and distances from the houses. STP levels were highest near poultry houses. A distance from poultry houses was identified that resulted in the best fit with observed STP levels (1500-2500m). This indicates the majority of poultry waste is land applied within 2500m of poultry houses.

Gade (1998) estimated mean annual adjusted loads entering Lake Tenkiller at Horseshoe Bend are 228,000 kg P/yr. He estimated that 83.5% of P is nonpoint source pollution (190,000 kg/yr). Gade estimated that at Horseshoe Bend, the mean annual concentration of total P was 0.23 mg/l with 0.15 mg/l from nonpoint sources, 0.02 mg/l from background sources and 0.06 mg/l from point sources.

Storm et al. (1996) used SIMPLE (Spatially Integrated Model for Phosphorus Loading and Erosion) in the Illinois River basin. They used 1985 NRCS poultry house survey to calculate poultry waste P but noted there was significant expansion of the poultry industry in the Oklahoma portion of the watershed from 1985 through 1992. For the model run that considered continuous loading of P from poultry over 25 years, the average increase in P load is 324 percent. P loading was calculated at 2.30 kg/ha per year from pastures after P was applied for 25 years. Storm et al. (1996) noted that long-term reductions in P loading can only be accomplished by exporting animal manure from the watershed. They indicated that to prevent excessive buildup of soil P, litter should be diverted to fields deficient in P, and those fields with excessive soil P levels should discontinue use of poultry litter and receive nitrogen from commercial fertilizers.

Storm et al. (1996) indicated that pasture areas account for 95 percent of total nonpoint source P loading to the basin with most of this coming from pastures receiving poultry waste. They estimated that 76 percent of total P load in the IRW comes from 6 subwatersheds: Flint, Benton, Osage, Clear and Fork; although these watersheds represent 56 percent of the basin area. They indicated that overall 66 percent of P was from nonpoint source pollution (Note significant P reductions in point sources began in 2003 so this proportion would be expected to be much higher now).

Storm et al. (2006) used the SWAT in the IRW and calculated 330,000 kg/yr of total phosphorus (88,000 kg/yr was in soluble mineral forms) reached Lake Tenkiller between 1997 and 2001. They indicated point sources of P to be 35% of this total and application of litter being responsible for 15% of total phosphorus load. However, they note "This does not include the effect of increased soil phosphorus from years of poultry litter application, which increased total phosphorus load. Therefore, if litter application was suddenly eliminated, the phosphorus load would be reduced by approximately 15%. Total phosphorus load due only to elevated soil phosphorous from the application of litter was not estimated." They note that 50% of total P loads were from other NPS sources, but they did not determine the portion of this attributable to poultry.

A draft TMDL analysis was performed on the IRW and Lake Tenkiller. In reviewing the sources of nutrients, a 1989 Soil Conservation Service (USDA-SCS, 1989) inventory was reviewed that estimated more than 93,400,000 chickens and other poultry are produced in the basin each year, producing 366,000,000 kilograms of manure. Gade (1998) indicates the poultry litter cleaned from poultry houses is spread over open pastures and barren fields. The report concludes that eutrophication in Lake Tenkiller is most sensitive to changes in P loading. A 25 percent reduction in P loading was required for lake water quality to satisfy the target criteria. Point sources were estimated to contribute 23% of P to Lake Tenkiller while urban and cropland contribute 5.6% of P, and pasture (with litter) contributes 56% of P.

Smith et al. (1997) analyzed HUCs (watersheds) to identify the contributors of nutrients to streams and rivers. For the Illinois River Watershed, they found that livestock contributed 93.01 kg P per square km per year (out of a total of 118.29 kg P per square km per year), while point sources contributed 5.33 kg P per square km per year and fertilizer contributed 8.52 kg P per square km per year. The Smith et al. (1997) analysis indicates livestock are responsible for 78.63% of P in the Illinois River while point sources represent 4.5% and fertilizer represents 7.21%.

Smith and Alexander (2000) mapped P contributions from livestock as shown in the figure below (Figure 2.3). The Illinois River Watershed was identified as having between 50 and 83% of P loads in runoff attributable to livestock (more than 78% based on Smith et al. (1997)). They found that compared to national data, the Illinois River P contributions from livestock are among the highest in the nation.

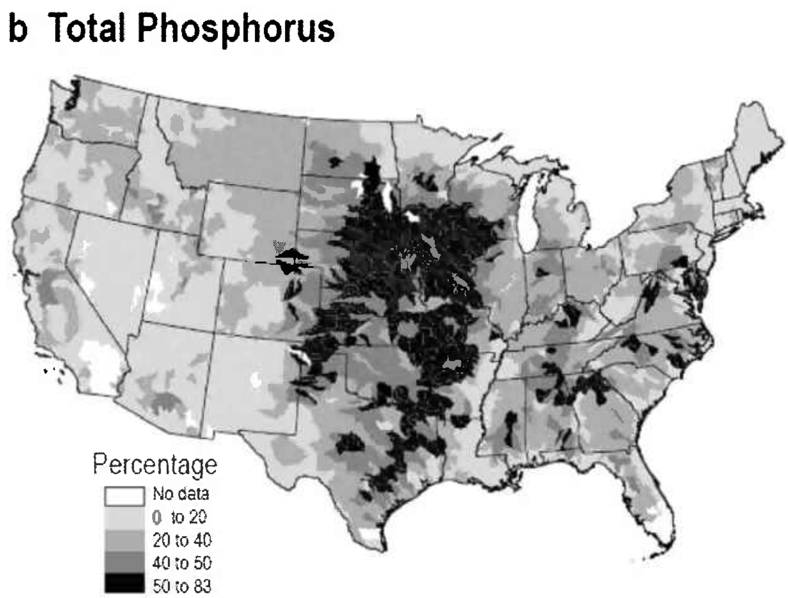


Figure 2.3. Contributions of animal agriculture to nutrient export from hydrologic units (watersheds) (from Smith and Alexander (2000))

Appendix A summarizes additional journal papers that complement the reports and literature reviewed in this section. These materials further support the analysis conducted throughout this report.

3. Poultry Waste and P Generation

Annual poultry waste generated in the Illinois River Basin was calculated using several sources of data. ***The analyses indicate each of the defendants' poultry operations within the Illinois River Watershed (IRW) produces a substantial amount of poultry waste and phosphorus. Calculated poultry waste produced within the IRW range between 354,000 and more than 500,000 tons annually. Phosphorus content of the poultry waste ranges from 8.7 million to nearly 10 million pounds annually.***

3.1 Poultry Production Data from Integrators
The 2001-2006 poultry production data for the Illinois River Basin provided by the integrators (Table 3.1) was used to calculate poultry waste and phosphorus (P) production. Not all integrators provided production data by type of poultry. Therefore, it was necessary to estimate the number of poultry by type for Tyson and Simmons. This was done by using the number of houses of each type of poultry by integrator created by Dr. Fisher (Fisher, 2008) and the average poultry production by type per house from the Arkansas Soil and Water Conservation Commission to estimate the proportion of poultry type for Tyson and Simmons. The Cobb data were combined with Tyson data.

Poultry waste production was calculated using waste values from the USDA Agricultural Waste Management Field Handbook, Ch.4 - Ag Waste Characteristics. The average weights of poultry by type were obtained from the Arkansas Soil and Water Conservation Commission data.

Table 3.1. Poultry Production in the Illinois River Basin Provided by Defendants' Discovery Responses

Defendant	2001	2002	2003	2004	2005	2006
Cal-Maine	1,135,998	879,281	633,656	403,739	200,000	0
Cargill	3,058,603	3,032,295	3,381,331	3,545,084	3,381,451	2,305,422
Cobb	1,189,358	1,279,798	1,237,193	1,250,237	1,243,562	1,244,481
George's	19,972,941	20,082,206	21,312,971	23,535,964	26,524,368	27,479,391
Peterson	13,277,715	14,454,936	14,897,458	20,981,977	18,166,724	16,887,638
Simmons	15,400,000	17,600,000	18,600,000	25,400,000	31,600,000	27,400,000
Tyson	87,027,895	88,142,559	90,098,641	95,023,680	89,719,497	88,639,337
TOTAL	140,870,901	145,267,093	149,255,914	170,140,681	170,835,602	163,956,269

The annual poultry waste and P produced by poultry based on poultry production data provided by the defendants are shown in Table 3.2 for the years 2001-2006. Phosphorus in the poultry waste shown in Table 3.2 is consistent with calculations obtained in performing a P mass balance for the Illinois River Watershed (as setout in Section 7 of this report and Appendix B). Waste ranges from nearly 420,000 tons in 2001 to more than 482,000 tons in 2004. Phosphorus in the poultry waste ranges from more than 8.7 million pounds in 2001 to nearly 10 million pounds in 2004.

Table 3.2. Poultry Waste and P Production within the IRW Based on Defendant Supplied Poultry Production Data

Year	Total Waste (tons)	Total P (lbs)
2001	420,555	8,732,752
2002	425,308	8,801,173
2003	440,920	9,176,463
2004	482,407	9,975,305
2005	476,649	9,819,383
2006	445,364	9,000,113

The annual poultry waste produced by integrator based on defendant supplied poultry production data is shown in Table 3.3. Each defendant produces a substantial amount of waste with Tyson producing approximately ½ of the waste.

Table 3.3. Poultry Waste by Defendant within the IRW Based on Defendant Supplied Poultry Production Data for 2001-2006

	Poultry Waste (tons)					
Year	Cal-Maine	Cargill	Georges	Peterson	Simmons	Tyson+Cobb
2001	18,626	45,086	69,510	27,970	40,247	219,116
2002	14,561	44,698	67,494	30,450	45,996	222,110
2003	10,821	49,843	73,401	31,382	48,610	226,862
2004	6,712	52,257	73,730	44,199	66,381	239,128
2005	3,135	49,845	76,879	38,269	82,585	225,936
2006	0	33,984	80,943	35,574	71,608	223,256

The annual P produced in poultry waste by integrator based on defendant supplied poultry production data is shown in Table 3.4. Each of the defendants' poultry operations produce a substantial amount of P in poultry waste with Tyson's producing approximately ½ of P in poultry waste.

Table 3.4. Phosphorus in Poultry Waste by Defendant within the IRW Based on Defendant Supplied Poultry Production Data for 2001-2006

	P in Poultry Waste (lbs)					
Year	Cal-Maine	Cargill	Georges	Peterson	Simmons	Tyson+Cobb
2001	396,398	1,484,311	1,452,470	543,414	768,007	4,088,152
2002	311,363	1,471,544	1,404,951	591,594	877,722	4,143,999
2003	233,511	1,640,927	1,532,054	609,705	927,592	4,232,673
2004	145,707	1,720,395	1,522,252	858,725	1,266,712	4,461,513
2005	71,837	1,640,986	1,571,747	743,505	1,575,910	4,215,398
2006	0	1,118,799	1,658,320	691,157	1,366,453	4,165,384

3.2 USDA Agriculture Census Data

In calculating poultry waste generated in the Illinois River Basin using the 2002 USDA Agriculture Census data, poultry were allocated to the basin using the proportion of pasture within counties to assign the proportion of poultry in the county to the basin. This approach calculated approximately 528,000 tons of poultry waste per year generated in the IRW.

Annual poultry waste generation was also calculated using 2002 USDA Agricultural Census data by allocating poultry to the basin proportional to the area of each county within the watershed. Calculated annual poultry waste in the IRW using this allocation approach is approximately 414,000 tons per year.

3.3 Arkansas Soil and Water Conservation Commission Data

The Arkansas Soil and Water Conservation Commission 2007 Poultry Registration data on poultry production in the Illinois River Basin were used to estimate poultry waste production in the basin. This data contained the type of poultry, weight, number, number of flocks, and number of houses. These data were provided for poultry operations that were within the basin within Benton and Washington counties. The average poultry production by type by house was computed from these data as was the average weight of poultry.

The number of active poultry houses with known integrators within the Oklahoma portion of the basin was obtained from Dr. Fisher (Fisher, 2008). These houses had an assigned poultry type as well. Poultry numbers for the Oklahoma counties were computed using the average production numbers by type of poultry from the Arkansas Soil and Water Conservation Commission data.

The poultry waste values provided by the Arkansas Soil and Water Conservation Commission used equations that are unrealistic with regard to the amount of poultry waste produced per bird as removed from poultry houses. The equations used by the Arkansas Soil and Water Conservation Commission to compute poultry waste calculate the amount of waste excreted on a dry weight basis (amount of waste excreted with all water removed and without inclusion of bedding materials). Therefore, poultry waste production was calculated using waste values from the USDA Agricultural Waste Management Field Handbook, Ch.4 - Ag Waste Characteristics. The average weights of poultry by type were obtained from the Arkansas Soil and Water Conservation Commission data.

The calculated annual poultry waste production using this approach within the IRW is approximately 477,000 tons. The poultry house data prepared by Dr. Bert Fisher that identified integrator and type of poultry were used to calculate the proportion of each poultry type produced by each integrator (Fisher, 2008). Using this information and total waste production for each type of poultry, the litter production within the IRW for each integrator was computed and is shown in Table 3.5.

Table 3.5. Calculated Annual Waste Production (tons) by Integrator Using Arkansas Soil and Water Conservation Commission Data and USDA Waste Characteristics Field Manual

Type	Poultry Waste Production (tons/yr)					
	Cal-Maine	**Cargill**	**Georges**	**Peterson**	**Simmons**	**Tyson**
Breeder	456	4,785	5,468	684	7,974	25,518
Broiler	0	1,018	56,006	38,950	58,552	148,162
Cornish	0	0	0	0	0	11,103
Turkey	0	52,073	0	0	0	0
Layer	12,362	0	11,411	6,657	0	6,657
Pullet	349	0	5,239	524	3,842	20,084
Total	13,167	57,876	78,125	46,814	70,368	211,523

The Arkansas Soil and Water Conservation Commission data show the following amounts of poultry waste generated within the Illinois River Watershed (Table 3.6). The poultry waste estimates by the Arkansas Soil and Water Conservation Commission use equations that greatly under predict poultry waste generation per bird as it would be removed from poultry houses. The equations used by the Arkansas Soil and Water Conservation Commission to compute poultry waste calculate the amount of waste excreted on a dry weight basis (amount of waste excreted with all water removed and without inclusion of bedding materials).

Table 3.6. Arkansas Soil and Water Conservation Commission (ASWCC) Estimate of Poultry Waste Generated in the Illinois River Watershed. Note the Equation Used by ANRC Underestimates Waste Production as Removed from Poultry Houses. Equation Estimates Waste Production on a Dry Weight Basis Without Bedding.

	ASWCC Poultry Waste Generated in IRW (tons)			
County	2004	2005	2006	2007
Benton	56,470	70,168	62,507	95,091
Washington	72,896	107,003	89,141	120,014

If the Arkansas Soil and Water Conservation Commission poultry waste estimate for 2007 (215,105 tons) is converted to waste as removed from poultry housing (includes some moisture and bedding material), the estimated poultry waste produced in Benton and Washington Counties is more than 376,000 tons. This is based on USDA Agricultural Waste Management Field Handbook, Ch.4 - Ag Waste Characteristics characterizations of poultry waste data (20 lbs dry weight per 1000 lbs broilers and 35 lbs as removed from housing including bedding per 1000 lbs broilers; to convert waste in Table 3.6 to as removed multiply values by 35/20 or 1.75).

3.3 Poultry Waste Generated within the IRW Based on Poultry House Data

Fisher (2008) calculated poultry waste generation within the IRW based on active poultry houses within the IRW, house sizes, type of poultry, integrator, and waste production data. Poultry houses within the IRW were identified from aerial photography and various data sources and observations were used to identify active houses (Fisher, 2008). The sizes of active houses were measured from aerial photography within a GIS. The integrator and type of poultry produced within each active house was identified from various records and observations (Fisher, 2008). The amount of waste produced per unit area of house by poultry type was calculated from data in animal waste management plans prepared under the supervision of the U. S District Court (N.D. Okl.) by the Eucha/Spavinaw Watershed Management Team. Additional details of the calculation are provided in Fisher (2008).

Table 3.7 shows the amount of poultry waste produced by each integrator within the IRW based on the data and calculations overviewed above. Each of the defendants produces a significant amount of poultry waste within the IRW.

Table 3.7
Poultry Waste Production (tons) Within the Illinois River Watershed Calculated from a Consideration of the Total Area of Active Poultry Houses Operated by a Known Defendant (from Fisher, 2008)

Defendant	Broiler	Breeder	Turkey	Pullet	Cornish	Hen	TOTAL	%
Cal-Maine		358		112		2,280	2,750	0.78%
Cargill		2,860	15,108				17,968	5.08%
Georges	49,813	5,911		2,489		1,888	60,101	16.98%
Peterson	35,063	491		277		1,311	37,143	10.49%
Simmons	58,724	5,757		1,818			66,299	18.73%
Tyson	129,421	18,593		7,735	9,874	1,521	167,144	47.22%
Willowbrook			2,597				2,597	0.73%
TOTAL	273,022	33,970	17,704	12,430	9,874	6,999	**354,000**	
	77.12%	9.60%	5.00%	3.51%	2.79%	1.98%		

3.4 Literature Estimates of Poultry Waste and P in Poultry Waste in the IRW

Reports and published journal papers have estimated poultry waste and P in poultry waste within the IRW. The estimates in these reports as described below are consistent with the analyses presented in the preceding sections.

Willett et al. (2006) estimated more than 361,000 tons of poultry waste was generated and applied within the IRW annually. They estimated this waste contained more than 9,000 tons of P. They recommended that poultry waste be exported from the watershed to address water quality issues in the IRW.

In reviewing the sources of nutrients, a 1989 Soil Conservation Service (USDA-SCS, 1989) inventory estimated more than 93,400,000 chickens and other poultry are produced in the basin each year, producing 366,000,000 kilograms (403,000 tons) of manure. Vieux and Moreda

(2003) noted that the P generated by the poultry industry in the IRW is equivalent to a human population of 8 million people.

Smith et al. (1997) analyzed HUCs (watersheds) to identify the contributors of nutrients to streams and rivers. For the Illinois River Watershed, they found that livestock contributed 93.01 kg P per square km per year (out of a total of 118.29 kg P per square km per year), while point sources contributed 5.33 kg P per square km per year and fertilizer contributed 8.52 kg P per square km per year.

Nelson et al. (2002) found nearly 6,000,000 lbs of P annually were input into the Arkansas portion of the Illinois River Watershed (7,000,000 lbs if cattle are considered but Nelson et al. acknowledge that cattle are recycling P). Of the approximately 6,000,000 lbs of P, nearly 5,000,000 lbs of P were estimated to be from poultry litter application to pastures in the watershed.

The USDA SCS and FS (1992) estimated that poultry in the IRW generated twice as much manure as cattle in the IRW. They estimated poultry manure in the IRW contained 5 times as much P as cattle manure in the IRW.

3.4 Summary of Poultry Waste Generation in the IRW

Table 3.8 summarizes the poultry waste generation within the IRW by method and/or source. Poultry waste generated within the IRW ranges between 354,000 tons annually to more than 500,000 tons annually.

Table 3.8. Poultry Waste Generated in the Illinois River Watershed

Source	**IRW Poultry Waste (tons/yr)**
Dr. Fisher (Fisher, 2008)	354,000
Defendant supplied poultry and USDA waste coefficients (2001-2006)	421,000-482,000
USDA Census and USDA waste coefficients (2002)	414,000-528,000
Arkansas Soil and Water Conservation Commission Data, Dr. Fisher house data, USDA waste coefficients (2007)	477,000
USDA-SCS (1989)	403,000
Willett et al. (2006)	361,000

4. Poultry Waste Land Application

The common practice for poultry waste disposal is land application to pasture and cropped areas. A substantial amount of the defendants' poultry waste and P is land applied within the IRW annually. The poultry waste is applied during the rainy season from late winter through spring.

4.1 Poultry Waste Land Application Analysis

Fisher (2008) examined ODAFF records to document land application of the defendants' poultry waste within the IRW. Fisher's table summarizing this is shown in Table 4.1.

Table 4.1. Location of Waste Generation and Location of Waste Disposal by Defendant (from Fisher, 2008)

Defendant	Location of Waste Generation	Location of Waste Disposal				
		Not Given (tons)	Border ILLINOIS RIVER WATERSHED (tons)	Inside ILLINOIS RIVER WATERSHED (tons)	Outside ILLINOIS RIVER WATERSHED (tons)	Total (tons)
Aviagen	Not Given	0	0	0	146	146
	Inside ILLINOIS RIVER WATERSHED	360	0	110	0	470
	Border ILLINOIS RIVER WATERSHED	0	0	0	0	0
	Outside ILLINOIS RIVER WATERSHED	0	0	0	2559	2559
Cal Maine Foods	Not Given	0	0	0	0	0
	Inside ILLINOIS RIVER WATERSHED	69	0	3327	792	4188
	Border ILLINOIS RIVER WATERSHED	0	0	0	0	0
	Outside ILLINOIS RIVER WATERSHED	0	0	0	0	0
Cargill	Not Given	583	0	1472	0	2055
	Inside ILLINOIS RIVER WATERSHED	0	0	3066	30	3096
	Border ILLINOIS RIVER WATERSHED	0	5777	0	714	6491
	Outside ILLINOIS RIVER WATERSHED	0	2784	0	616	3400
Cobb-Vantress (Tyson)	Not Given	7032	752	10792	43191	61768
	Inside ILLINOIS RIVER WATERSHED	364	478	31737	555	33134
	Border ILLINOIS RIVER WATERSHED	0	3740	1721	1627	7088
	Outside ILLINOIS RIVER WATERSHED	1862	3336	2740	62078	70016
Georges Inc	Not Given	415	0	0	0	415
	Inside ILLINOIS RIVER WATERSHED	0	0	3165	0	3165
	Border ILLINOIS RIVER WATERSHED	0	1096	45	108	1249
	Outside ILLINOIS RIVER WATERSHED	0		270	114	384
Peterson Farms	Not Given	2778	90	240	1056	4164
	Inside ILLINOIS RIVER WATERSHED	0	1281	2959	633	4873
	Border ILLINOIS RIVER WATERSHED	0	5110	0	1679	6789
	Outside ILLINOIS RIVER WATERSHED	301	1043	180	10277	11801
Simmons Foods	Not Given	945	405	4544	2988	8882
	Inside ILLINOIS RIVER WATERSHED	184	2733	16103	1512	20532
	Border ILLINOIS RIVER WATERSHED	219	4891	636	984	6730
	Outside ILLINOIS RIVER WATERSHED	579	748	3589	29444	34360
Tyson Foods	Not Given	717	232	2305	2570	5823
	Inside ILLINOIS RIVER WATERSHED	117	2404	23678	420	26619
	Border ILLINOIS RIVER WATERSHED	300	4486	0	2327	7113
	Outside ILLINOIS RIVER WATERSHED	66	1258	515	17920	19759
Willow Brook Foods	Not Given	0	24	345	0	369
	Inside ILLINOIS RIVER WATERSHED	0	648	0	1120	1768
	Border ILLINOIS RIVER WATERSHED	0	1194	997	2400	4591
	Outside ILLINOIS RIVER WATERSHED	0	0	0	0	0

In recent years some poultry waste has been transported out of the IRW, largely due to a program in which BMPs Inc. receives a $10 per ton subsidy for poultry waste removed from the watershed. BMPs Inc. documents (Herron, 2006) indicate there had been a market for approximately 50,000 tons of poultry waste annually with this level of subsidy. The BMPs Inc.

document further indicates "It is clear that once the subsidy program ends, most of the litter will have to be sold locally, without additional assistance."

Fisher (2008) documented movement of some poultry waste out of the IRW as shown in Table 4.2. As the BMPs Inc. documents indicate, the amount of poultry waste that will be transported without a subsidy is likely to be very limited.

Table 4.2.
Tons of Poultry Waste Hauled from the Illinois River Watershed to Locations Outside the Illinois River Watershed by BMPs, Inc. and Georges' (2003-2006) (from Fisher, 2008)

Year	2003	2004	2005	2006	TOTAL
BMPs, Inc. Tons	0.00	905.88	14,783.57	59,736.56	**75,426.01**
Georges' Tons	8,877.60	11,406.30	19,651.13	9,282.45	**49,217.48**
TOTAL Tons	**8,877.60**	**12,312.18**	**34,434.7**	**69,019.01**	***124,643.50***
% of Poultry Waste Produced that was Hauled	**2.51%**	**3.48%**	**9.73%**	**19.50%**	***8.80%***

4.2 Proximity of Poultry Waste Land Application - Arkansas Soil and Water Conservation Commission

The Arkansas Soil and Water Conservation Commission data show the following amounts of poultry waste land applied within the Illinois River Watershed (Table 4.3). The poultry waste estimates and land application estimates use equations that greatly under predict waste generated per bird as it would be removed from poultry houses and land applied. The equations used by the Arkansas Soil and Water Conservation Commission to compute poultry waste calculate the amount of waste excreted on a dry weight basis (amount of waste excreted with all water removed and without inclusion of bedding materials). Most of the waste generated is shown as being transferred and thus the location of land application is not provided by the Arkansas Soil and Water Conservation Commission.

Table 4.3. Arkansas Soil and Water Conservation Commission Estimate of Poultry Waste Land Applied in the Illinois River Watershed. Multiply Values by 1.75 (See Section 3.3) to Obtain Actual Waste Mass Land Applied.

	Waste Land Applied in IRW (tons)			
County	2004	2005	2006	2007
Benton	11,440	7,925	5,935.75	36,180
Washington	24,457	19,269	20,009	30,010

4.3 Proximity of Poultry Waste Land Application – ODAFF Record Analysis
Dr. Fisher (Fisher, 2008), under the direction of Dr. Engel, examined ODAFF (Oklahoma Department of Agriculture, Food and Forestry) records of poultry waste land application. For the State of Oklahoma, these data indicated that 30% of poultry waste was land applied within the square mile in which it was generated (data resolution was to the nearest section or square mile). Sixty percent of poultry waste was land applied within 2 miles of where it was generated and 80% of poultry waste was land applied within 5 miles of where it was generated.

Analysis of ODAFF records for the IRW indicates a similar pattern with poultry waste applied even closer to where it was generated. ODAFF records specific to the IRW indicate 30% of poultry waste is land applied within the square mile in which it was generated, 67.5% was land applied within 2 miles, and 80% was land applied within 3.6 miles. The overwhelming majority of poultry waste generated within the IRW is land applied near where it is generated.

Dr. Fisher's analysis (Fisher, 2008) of nutrient management plans for poultry producers within Arkansas indicate a similar pattern of land application of poultry waste.

4.4 Poultry Waste Land Application Literature
The BMPs Inc. (2007) final report to the EPA indicated that poultry waste within the IRW has been land applied in large quantities leading to potential to impact water quality. The BMPs Inc. proposal for transport of a small portion of the poultry waste out of the IRW was built on this premise.

Sharpley et al. (2007) indicate "in many areas, manure is rarely transported more than 10 miles from where it is produced. As a result manure is often applied to soils that already have sufficient nutrients to support crop growth."

The USDA SCS and FS (1992) indicated that a significant part of the water quality problems in the IRW are a result of the *large volume of poultry waste generated and disposed of in the basin*. Rausser and Dicks (2008) assumed *all* poultry waste produced in the IRW was land applied within the IRW.

Nelson found nearly 6,000,000 lbs of P annually were applied to the Arkansas portion of the Illinois River Watershed (7,000,000 lbs if cattle are considered but Nelson et al. acknowledge that cattle are recycling P). Of this total, nearly 5,000,000 lbs of P applied in the Arkansas portion of the watershed were from poultry litter application to pastures.

Vieux and Moreda (2003) noted that the P generated by the poultry industry in the IRW is equivalent to a human population of 8 million people. They further indicated that poultry manure is stored and then applied to pastureland in the watershed.

Storm et al. (1996) found that a maximum poultry waste transport distance of 8000m (approximately 5 miles) from poultry houses in the IRW provided the best observed fit between estimated STP and observed STP.

Storm et al. (2006) applied all poultry waste within 5 km (approximately 3 miles) of poultry houses when modeling the IRW. This was based on their experiences and analysis of poultry waste transportation distance in the Eucha Spavinaw Watershed.

Other reports and literature in Section 2 "Review of Illinois River Watershed Studies - P Contribution" also indicate that poultry waste generated within the IRW is land applied within the IRW. Literature reviewed in Appendix A also indicates poultry waste is land applied near where it is generated.

4.5 Timing of Poultry Waste Application in the IRW

Dr. Fisher (Fisher, 2008) analyzed the timing of land application of poultry waste in the Oklahoma portion of the IRW using ODAFF records. Analysis of these data indicates the late winter and early spring are the primary period of poultry waste land application within the IRW. Based on disposal records from 1999 through 2004, approximately 63.4% of the poultry waste land disposed within the Illinois River Watershed is disposed during February through June as shown in Figure 4.1. This period of land application coincides with the period of greatest rainfall within the IRW, thereby increasing runoff of poultry waste to IRW waters.

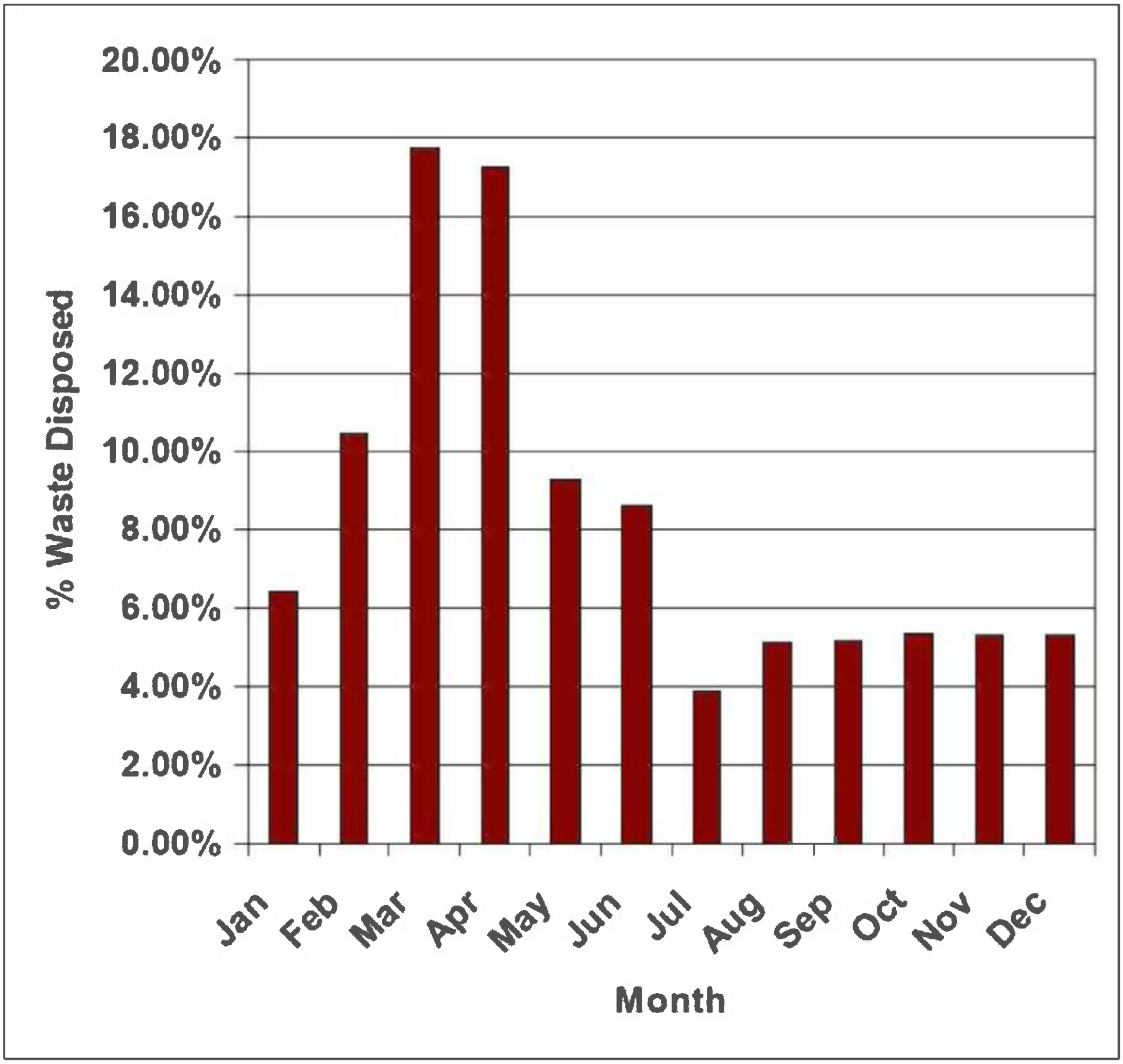


Figure 4.1. Timing of poultry waste disposal within the Oklahoma portion of the IRW determined from records maintained by ODAFF (1999-2004 data) (From Fisher, 2008).

5. Observed P Loads in the Illinois River Watershed

The P loads to Lake Tenkiller averaged approximately 505,000 lbs annually between 1997 and 2006. This represents a significant P load to the lake and is much greater per unit area than for other watersheds in the region.

The observed P loads to Lake Tenkiller indicate a substantial P load relative to other watersheds in the region (Tortorelli and Pickup, 2006 and Pickup et al., 2003). Table 5.1 provides USGS calculated P loads at the Tahlequah and Baron Fork USGS gauging stations (Tortorelli and Pickup, 2006 and Pickup et al., 2003). The P loads vary greatly from year to year due to weather variability that impacts P losses to streams and rivers and impacts water flows that carry P into Lake Tenkiller.

Table 5.1. USGS Computed Annual P Loads (Tortorelli and Pickup, 2006 and Pickup et al., 2003)

	Total Annual P (lb/yr)	
Years	**Tahlequah**	**Baron Fork**
97-99	307,000	32,800
98-00	511,000	124,000
99-01	621,000	135,000
00-02	559,000	154,000
01-03	331,000	59,000
02-04	355,000	120,000

USGS and OWRB samples analyzed for total P content were used along with USGS flow data to compute observed P loads at the Tahlequah, Baron Fork near Eldon, and Caney Creek gauging stations between 1997 and 2006. The LOADEST (load estimator) software (Runkel et al., 2004) was used along with these data in calculating P loads. Tortorelli and Pickup (2006) and Pickup et al. (2003) used this approach in computing P loads for the IRW. The approach used by Tortorelli and Pickup (2006) and Pickup et al. (2003) was used in calculating P loads. The R^2 for LOADEST calculated P and observed P is shown in Table 5.2. The fit between calculated P and observed P is a very good fit. LOADEST can be used to calculate P loads within the IRW.

Table 5.2. R^2 for LOADEST Calculated P and Observed P

	R^2		
Year	**Tahlequah**	**Baron Fork**	**Caney Creek**
1998	0.95	0.89	0.87
1999	0.95	0.96	0.87
2000	0.96	0.94	0.95
2001	0.94	0.93	0.97
2002	0.92	0.93	0.98
2003	0.90	0.92	0.98
2004	0.94	0.97	0.98
2005	0.95	0.98	0.99
2006	0.95	0.98	0.99

The IRW P loads calculated with LOADEST are shown in Table 5.3 and show substantial variation annually due to differences in rainfall and flow into Tenkiller.

Table 5.3. Observed P Loads Based on USGS and OWRB P Data and USGS Flow Data

	Total P (lb/yr)			
Year	**Tahlequah**	**Baron Fork**	**Caney Creek**	**Total**
1997	211,467	25,500	4,140	241,107
1998	422,906	39,887	9,024	471,817
1999	392,336	49,755	8,349	450,440
2000	771,454	298,307	55,787	1,125,548
2001	456,947	98,931	36,616	592,494
2002	301,474	52,666	16,574	370,714
2003	94,684	10,107	3,485	108,276
2004	631,798	459,054	57,086	1,147,938
2005	258,021	68,639	14,004	340,664
2006	128,415	58,300	10,574	197,289

Walker (1987) indicated that for the IRW, phosphorus concentration cannot be considered independent of flow, and thus averaging the concentrations independent of flow would yield invalid results. Thus, the use of the approach in LOADEST was necessary to account for the relationships between flow and P concentrations within the IRW.

For the period 1997 to 2006, the P loads to Lake Tenkiller range from slightly more than 197,000 lbs in 2006 to more than 1,147,000 lbs in 2004 as shown in Table 5.3. The average annual P loads to Lake Tenkiller were approximately 505,000 lbs between 1997 and 2006. Vieux and Moreda (2003) indicated that variability from year to year is expected in water quality constituents such as P if surface runoff is a dominant transport mechanism. They analyzed data for the IRW and found that surface runoff was the dominant transport mechanism for P in this watershed. Data summarizing the variability in flows within the IRW rivers are provided in Figure 5.1 and Table 5.4. Rainfall variability is summarized in Table 5.5.

The water flows to Lake Tenkiller for the period of 1997 to 2006 are much smaller than flows that have been experienced to Lake Tenkiller in the past (Table 5.4). If the IRW had experienced flows that were similar to historical flows (1950-2007) during 1997 to 2006, the observed P loads for 1997 to 2006 would have been significantly higher.

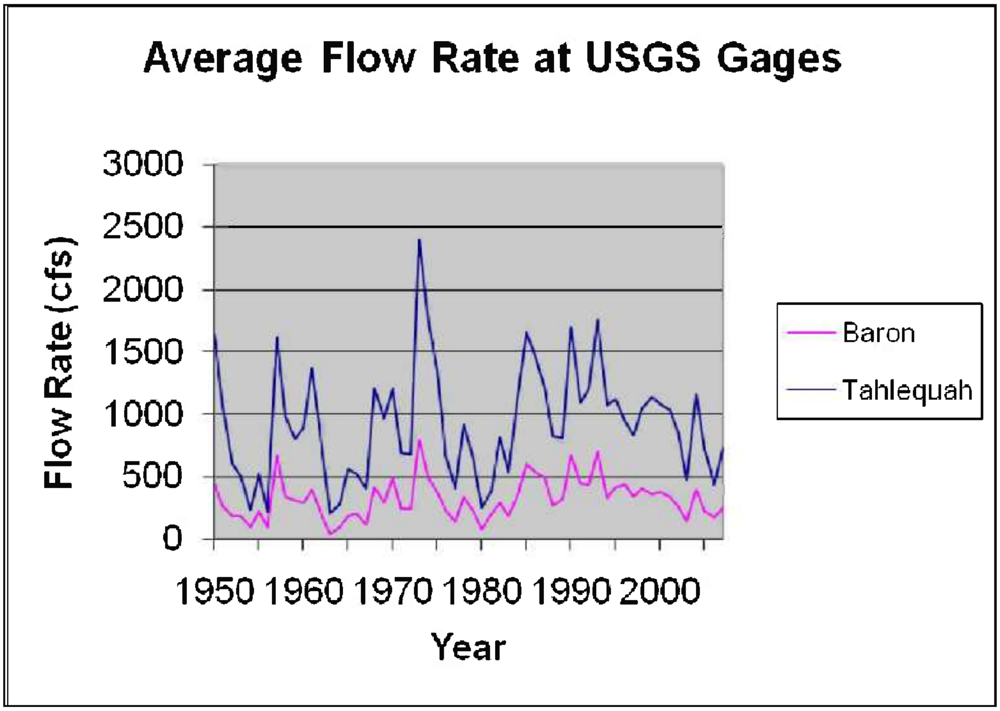


Figure 5.1. Annual Observed Daily Average Flow Rate at USGS Gauges at Tahlequah and Baron Fork near Eldon

Table 5.4. Summary of Annual Flow Data at USGS Gauges Tahlequah and Baron Fork near Eldon for 1950-2007 and 1997-2006

		1997-2006	**1950-2007**
Baron Fork	**Q ave (cfs)**	304	323
Tahlequah		878	922
Baron Fork	**Range (cfs)**	144-409	41-795
Tahlequah		439-1159	205-2393
Baron Fork	**St Dev**	95	163
Tahlequah		265	457

Table 5.5. Annual Rainfall Summary Statistics for Rain Gauge COOPID 35354 in the IRW

	Average Annual Rainfall (in)	St. Dev	Range (in)
1950-2006	50.15	10.24	27.51-81.14
1997-2006	51.34	7.20	36.44-59.65

6. Point Sources of P in the Illinois River Watershed

A portion of the P in the IRW rivers and streams and reaching Lake Tenkiller is from Waste Water Treatment Plant (WWTP) discharges. Waste Water Treatment Plants within the IRW discharge P into the streams and rivers of the IRW that eventually reaches Lake Tenkiller. ***P discharges from IRW WWTP have changed over time. WWTP P discharges into IRW streams and rivers peaked at slightly more than 204,000 lbs annually in the late 1990s and early 2000s. Beginning in 2003, WWTP P discharges decreased to a little more than 90,000 lbs annually in the IRW due to changes in WWTP technology. The defendants' processing facilities discharge a significant amount of P to WWTPs and thus contribute to point P sources within the IRW.***

WWTP contributions of P to the Illinois River for three time periods are shown in Table 6.1. Changes in WWTP technology significantly reduced P contributions beginning in 2003 (from more than 204,000 lbs annually to a little more than 90,000 lbs annually). Recent P discharges from WWTPs were computed from recent WWTP discharge data (1999-2007 Permit Compliance System (PCS) data) from the Oklahoma Department of Environmental Quality and the Arkansas Department of Environmental Quality. WWTP discharges prior to 2003 were obtained from Gade (1998), representing P discharges for the 1990s through 2002. Nelson reported similar WWTP discharges of P for the Arkansas portion of the Illinois River for the late 1990s through 2006. Nelson observed a significant reduction in WWTP P discharges beginning in 2003. Discharges from Arkansas WWTPs represent the majority of WWTP P discharges into the IRW streams and rivers.

Table 6.1. WWTP Total P Discharge to Streams and Rivers within the IRW

	Mid 70s	**Early 90s**	**2003-present**
WWTP	**P Load (lb/yr)**	**P Load (lb/yr)**	**P Load (lb/yr)**
Springdale	70,841	95,128	25,112
Siloam Springs	23,014	22,046	29,638
Fayetteville - Noland	0	9,921	5,147
Rogers	41,515	47,619	16,206
Lincoln	1,767	2,646	2,336
Prairie Grove	2,409	2,646	3,285
Tahlequah	19,235	10,362	2,738
Stillwell	15,675		2,519
Westville	2,502	6,393	840
Gentry	1,767	3,748	2,336
Watts		1,102	0
Midwestern nursery		1,323	0
Cherokee Nation		1,168	0
Stillwell Cannery			
Total	**178,724**	**204,101**	**90,155**

The WWTP P discharges from the late 1970s and early 80s were obtained from the Roberts/Schnorick and Associates report of 1984 and two EPA Environmental Lab (1977) reports as shown in Table 6.2. The Roberts/Schnorick report provides WWTP discharges for 1979-1984 and the EPA values are mid 1970s values. The Roberts/Schnorick P discharge values are reported as lbs/day of phosphorus. Comparing Roberts/Schnorick P discharges for the same WWTPs with the EPA values and values reported for later in the 1980s, the Roberts/Schnorick P discharges are not phosphorus but are phosphate (P_2O_5). The discharges converted to P are shown in the far right column in Table 6.2.

Table 6.2. WWTP P Discharges into IRW Streams and Rivers for Late 1970s and Early 1980s

	Annual P Discharge (lbs/yr)		
WWTP	**Roberts/Schnorick (1984) as P_2O_5**	**Environmental Lab Las Vegas (1977)**	**Roberts/Schnorick as P**
Springdale	161,002		70,841
Siloam Springs	52,305		23,014
Fayetteville - Noland	0		0
Rogers	94,353		41,515
Lincoln	4,015	1,312	1,767
Prairie Grove	5,475		2,409
Tahlequah	46,173	19,235	20,316
Stillwell	0	15,675	0
Westville	0	2,502	0
Gentry	4,015		1,767

The Roberts/Schnorick report indicates there were three permitted point source discharges in the upper Illinois River system in addition to the WWTPs they considered. These were the Centerton Hatchery, the Swepco Flint Creek Power Plant and Gates Rubber. No P discharges from these sources were reported (permits did not include P discharge) or considered in the Roberts/Schnorick Illinois River assessment report.

The historical WWTP P discharges into streams and rivers of the IRW are shown in Table 6.3. These were needed for modeling P Loads (Section 10). The late 1970s/early 1980s WWTP P discharges shown in Table 6.2 were used to compute a waste discharge per person and the resulting value was used to compute WWTP P discharges for 1950, 1960 and 1970. WWTP P discharges from Table 6.1 were used for 1980 to present.

Table 6.3. Estimated WWTP P Discharges Historically into Streams and Rivers of the IRW

Year	**IRW population**	**Estimated P (kg/yr)**	**Estimated P (lb/yr)**	**Observed P (lb/yr)**
1950	83,874	46,701	102,958	
1960	91,552	50,977	112,383	
1970	125,496	69,877	154,050	
1980	165,695			178,724
1990	192,439			204,101
2000	280,383			90,155

A substantial amount of the P discharged from the Springdale WWTP is from industrial sources. Table 6.4 shows industrial P flows to the Springdale WWTP. The defendants discharge more than 88% of the industrial P to the Springdale WWTP (more than 257,000 lbs annually). Historically (before 2003), the Springdale WWTP P discharges were 44% of IRW WWTP P discharges and currently (since 2003) represent about 28% of IRW WWTP P discharges.

Table 6.4. P Discharges to Springdale WWTP from Industrial Sources

Facility Name	Dates	P (lb/d)
Allen Canning Co	10/87-12/90	11.8
Allen Canning Co	12/94-11/01	80.8
Blaylock Company	12/94-11/02	2.8
Cargill, Inc.	**12/94-11/03**	**118.8**
Cintas Corporation	12/94-11/03	7.6
D. B. Foods, Inc	12/94-11/01	17.4
Danaher Tool Group	10/91-9/07	29.7
Danaher Tool Group	10/87-9/91	6.7
George's Debone	**2/97-11/01**	**30.5**
George's Further Processing	**12/02-11/03**	**52.0**
George's, Inc.	**12/94-11/03**	**115.5**
J. B. Hunt Transport, Inc	12/94-11/03	0.9
J. B. Hunt Transport, Inc	12/94-11/03	0.4
Monark Egg	10/87-9/90	12.2
Midcentral Egg	10/90-9/91	6.4
Pappas Foods, L.L.C.	12/00-11/01	4.1
Sonstegard Foods Inc. of Arkansas	12/02-11/03	0.0
Superior Linen Service	7/98-11/03	3.1
Triple T Foods, Inc.	12/94-11/03	3.9
Tyson Foods, Inc. - Berry St.	**12/94-11/03**	**244.0**
Tyson Foods, Inc. - Hog Trailer Wash	**8/95-11/03**	**14.5**
Tyson Foods, Inc. - Randall Rd.	**12/94-11/03**	**123.8**
Tyson Research & Technology	**10/95-11/03**	**6.1**
Total		893.0

The defendants make a substantial contribution to point source P discharges from the Springdale WWTP. The daily P contribution to the Springdale WWTP from people is approximately 138 lbs/day (2000 census population of Springdale is 45,798 people * 1.1 lb P/person per year / 365 days/yr). The defendants discharge 705 lbs P per day to the Springdale WWTP representing 79% of P inflow to the Springdale WWTP. Based on these inflows to the Springdale WWTP, the defendants' P discharge from the Springdale WWTP represents 35% of total WWTP P discharges into IRW rivers and Lake Tenkiller historically (44% of WWTP P from Springdale * 79% of P to Springdale from defendants = 35%) (before 2003) and currently (since 2003) represents more than 22% of total WWTP P discharges to IRW rivers and Lake Tenkiller (28 % * 79% = 22%). The defendants' portion of P discharges through the Springdale WWTP represents a substantial amount of WWTP P discharges into IRW rivers and Lake Tenkiller.

WWTP water discharges to the IRW streams and rivers since 2003 are shown in Table 6.5 as reported in the PCS data.

Table 6.5. WWTP Water Discharges Since 2003

WWTP	**Flow (mgd)**
Springdale	12.4
Siloam Springs	2.68
Fayetteville - Noland	5.18
Rogers	5.71
Lincoln	0.44
Prairie Grove	0.32
Tahlequah	2.65
Stillwell	0.81
Westville	0.14
Gentry	0.44

7. Phosphorus Mass Balance

The movement of phosphorus into and out of an area (e.g., a mass balance analysis) provides insight into the primary sources of P within an area such as a watershed. ***A P mass balance for the Illinois River Watershed indicates poultry production is a substantial contributor to P within the Illinois River Watershed. Poultry production within the Illinois River Watershed is currently responsible for more than 76% of P movement into the watershed.***

7.1 P Mass Balance Analysis for the IRW

Under my direction, M. Smith performed of an analysis that examined the flow of P into and out of the IRW system (e.g., a mass balance) (see Appendix B for full analysis). The findings include:

1. Poultry production is currently responsible for more than 76% of the net annual phosphorus additions to the IRW.
2. Historical data indicates poultry production has been the major contributor of phosphorus to the watershed since 1964. Prior to 1964, dairy cattle were responsible for the majority of the phosphorus contribution.
3. From 1949 to 2002, there was more than 219,000 tons of phosphorus added to the IRW. Almost 68% of that addition, more than 148,000 tons, was attributable to poultry production.
4. Other contributing sources of phosphorus (net additions) include commercial fertilizers (7.5%), dairy cattle (5.2%), humans (3.2%), swine (2.9%), industrial sources – mostly poultry processing facilities (2.7%) and beef cattle (1.7%). The remaining sources of phosphorus evaluated in this study, which include urban runoff, golf courses, wholesale nurseries, and recreational users, are negligible (< 1%).
5. Of the three phosphorus exports from the watershed (harvested crops, harvested deer, and water leaving Lake Tenkiller through the spillway) outflow of phosphorus through the spillway at the south end of Lake Tenkiller was the largest. According to current estimates, the flow of water through the spillway removes just under 1.25% of the total annual phosphorus additions to the watershed. The remaining two phosphorus exports combined remove just over 0.25% of current annual phosphorus additions to the watershed, totaling a 1.5% removal of current phosphorus additions.

Figure 7.1 shows the current additions of P to the IRW by source. As noted above, poultry is responsible for the overwhelming majority (76%) of P additions to the IRW.

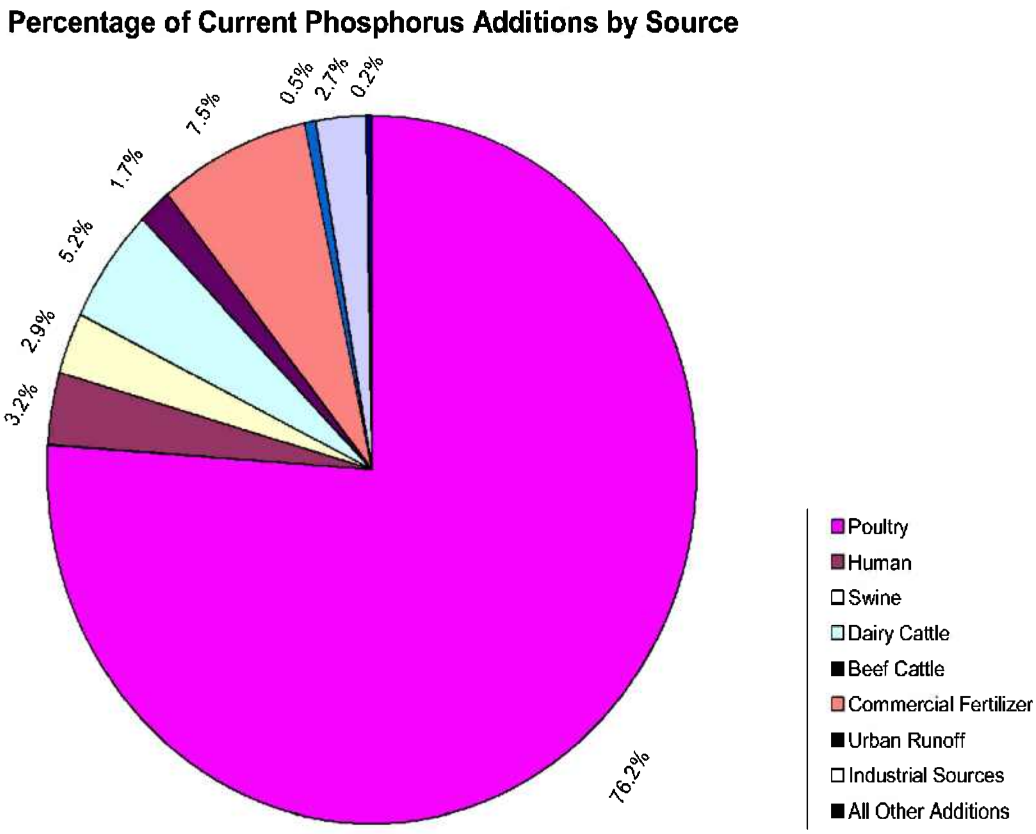


Figure 7.1 Phosphorus Additions to the IRW as a Percentage by Source

7.2 P Mass Balance Literature

The scientific literature describes similar approaches as that used by the mass balance analysis set forth in Appendix B. In addition, some of these studies include portions of the IRW and reached similar conclusions as those highlighted above and in Appendix B.

Slaton et al. (2004) indicate that a fundamental component of nutrient management strategies is to determine the balance between nutrient inputs and outputs to identify areas where soil nutrient inputs are greater than removals. Slaton et al. (2004) termed such areas as "critical areas" and indicated that nationally many such areas have been identified and these areas coincide with concentrated animal production. They identified critical nutrient areas within Arkansas by dividing Arkansas into 9 geographic regions and computing a nutrient mass balance for each region. Nutrient removal by crops and nutrient inputs from livestock production were computed based on Agricultural Statistics Service data. Livestock nutrient inputs to soils were computed based on livestock numbers and nutrient content of livestock waste by species. Nutrients contained in beef cattle manure were ignored by Slaton et al. (2004) as they indicate "a large proportion of these nutrients are obtained from forage and deposited directly (i.e., recycled) to pastures during grazing rather than collected in lagoons or stockpiled from confined animal production facilities." Nutrient inputs from inorganic fertilizers were computed based on Arkansas fertilizer sales data.

Slaton et al. (2004) found that the district with the greatest excess N and P was northwest Arkansas which includes Benton and Washington counties. This region was estimated to have an accumulated P in soils for a 5 year period of 32 kg/ha. Kellogg et al. (2000) and Kellogg (2001) conducted a national nutrient balance assessment and identified the Illinois River Watershed and the northwest Arkansas and northeast Oklahoma area as being vulnerable to P loss in runoff due to excess manure based P being land applied. Sharpley et al. (2007) indicate that the spatial separation of crop and poultry production systems results in a large-scale one-way transfer of nutrients from grain to poultry producing areas. This is certainly the case for the IRW.

A similar mass balance approach was used by Mallin and Cahoon (2003) to estimate nutrients in livestock waste within North Carolina. Stow et al. (2001) also used a similar approach in computing nutrient inputs into the Neuse River Watershed in North Carolina. Cassell et al. (2002) used a mass balance and modeling approach in exploring P losses from watersheds. Sharpley et al. (2007) computed P surpluses for farms and found that poultry farms had the greatest P surpluses. Tarkalson and Mikkelsen (2003) examined P surpluses on a typical poultry farm and found that an annual surplus of 65 kg P per ha was available for broiler farms and indicated this presents a potential hazard to surface water quality.

The accumulation of excess P in soils is problematic, since soil P levels are correlated to the amount of P in runoff (Slaton et al., 2004). One of the solutions to this problem is the transportation of manure outside the critical watersheds with substantial animal production to row-crop production areas (Slaton et al., 2004). However, they indicate that "the low economic value of poultry litter, which represents the majority of organic nutrient sources produced in Arkansas, as a fertilizer nutrient source is believed to prohibit its transport to the primary row-crop production area." Slaton et al. (2004) conclude that their assessment may help reinforce the thought that current nutrient application strategies in western Arkansas are not sustainable without the danger of creating and/or exacerbating water quality issues from excessive nutrients.

Nelson et al. (2002) performed a phosphorus mass balance for the Arkansas portion of the Illinois River Watershed. Sources of P identified in the mass balance were livestock manure, inorganic fertilizers, sludge applications and point source inputs from wastewater treatment plants. Livestock production was estimated based on agricultural statistics by county and the portion of these livestock within the watershed was allocated based on land use (pasture). A reference value of P excreted by livestock was used with the livestock production numbers to estimate total P by livestock species. Nelson et al. (2002) included dairy and beef cattle in the mass balance calculations but indicated that "beef and dairy are the only animals that obtain the majority of their phosphorus through grazing. Therefore, they are consuming plant phosphorus and depositing manure phosphorus (i.e., no net change in phosphorus in IRDA (Illinois River Drainage Area))." A presentation to Cargill producers also acknowledges this. The annual accumulation of P in pasture soils was estimated at 8 to 9 kg P/pasture acre per year. This was largely due to the application of excess poultry litter to pastures (CARTP016287-CARTP016290).

Nelson found nearly 6,000,000 lbs of P annually were applied to the landscape in the Arkansas portion of the Illinois River Watershed (7,000,000 lbs if cattle are considered but Nelson et al. acknowledge that cattle are recycling P). Nearly 5,000,000 lbs of P were estimated to be from poultry litter application to pastures in the watershed. This represents approximately 83% of P inputs to the watershed annually.

Sharpley et al. (2007) conclude that "the capacity of watersheds to assimilate nutrients, assuming some transport of manure from P-rich to P-deficient areas, should be determined and used in strategic planning of future development, expansion, or realignment of poultry operations."

7.3 Soil Test P Data for Illinois River Watershed

The soil test phosphorus data for the Illinois River Watershed area indicate soil P levels have been built to excessive levels well beyond agronomic requirements as a result of poultry litter application to pastures in most areas (Johnson, 2008). The soil test phosphorus levels within the IRW (Table 7.1) support the P accumulation described in the IRW mass balance. These high STP levels in the IRW contribute to P loads in IRW streams and rivers and to Lake Tenkiller.

Table 7.1. Soil Test Phosphorus Levels in the IRW Indicate Elevated P Levels Due to Poultry Waste Application

County	Soil Test P	Years
Benton	504	2000-2007
Washington	446	2000-2007
Adair	182	1995-2006
Cherokee	75	1995-2006
Delaware	160	1995-2006
Sequoyah	50	1995-2006

Background STP levels in the IRW can be estimated from samples obtained at the Nickel Reserve within the IRW. STP values for forested areas at the Nickel Reserve were 17.4 to 20.6 lb/acre for the top 6 inches of soil. These values would represent a background STP value within the IRW as no P has been applied to these areas in the form of fertilizer or livestock waste. STP values for pastured areas at the Nickel Reserve were 28 to 37.4 lbs/acre for the top 6 inches of soil. Livestock waste and fertilizer have not been applied to these areas for many years, so these STP values would represent likely background levels for pastures that are occasionally grazed by livestock. STP values within the IRW soils as depicted in Table 7.1 indicate elevated STP values relative to background STP values.

8. P Loads in the IRW Based on Continued Poultry Waste Land Application

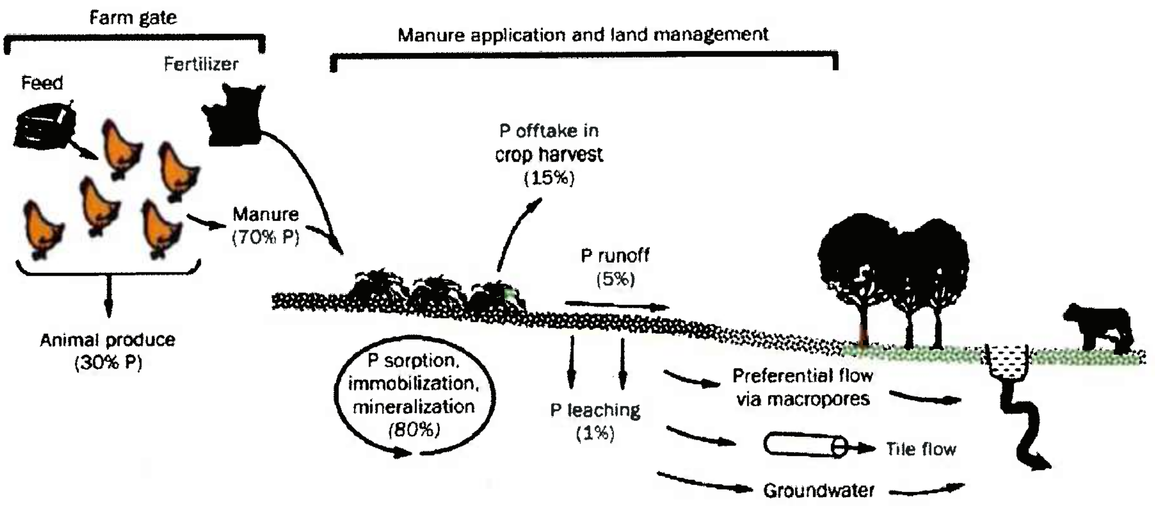
Researchers have observed that annual P loads to streams and rivers are approximately 5% of the annual application of poultry litter or annual poultry litter combined with other P applied to the landscape in circumstances where there has been a buildup in STP. Based on the annual application of poultry waste to pastures within the Illinois River Watershed and literature values of P loads to water, application of poultry waste to pastures in the Illinois River Watershed is a substantial contributor to P in the streams and rivers of the watershed and to Lake Tenkiller. ***Average annual P loads to water in the Illinois River Watershed attributable to poultry waste application to pastures is calculated at between 432,000 lb to nearly 500,000 lb annually based on poultry waste P application to the landscape and literature P loss coefficients.***

8.1 P Loads Based on P Application to Landscapes and P Loss Coefficients
P loads to runoff can be computed based on the P applied to landscapes and relationships between P in livestock waste that is spread on the land and P that is accumulated in the soil. Sharpley et al. (2007) indicates 5% of poultry waste applied to land is lost in surface runoff (see Figure 8.1). They indicate such losses are agronomically small (generally less than 2 kg P per ha). However, such losses can have significant environmental impact. With continued P application in excess of agronomic needs, the portion of P lost with runoff could be greater than 5% (see Section 10 of this report) (Stow et al., 2001).

Willett et al. (2006) modeled phosphorus loads from poultry waste application to agricultural areas in the Illinois River Watershed within Arkansas and Oklahoma. In their modeling, 33% of P was available to the crop and 67% went to building P in the soil. Of the P going to the soil, 8% was modeled as lost in runoff. Thus, 5.36% (67% of P to soil * 8% of this lost in runoff) of P applied through poultry litter applications in the watershed was lost in runoff each year (Willet et al., 2006).

Nelson et al. (2002) performed a P mass balance for the Arkansas portion of the Illinois River Watershed. They used observed P data in the Illinois River to compute the amount of annual P applied to the landscape that is exported from Arkansas in the Illinois River. Point sources of P were removed from the observed P in the Illinois River before computing the percentage of P that was applied to the landscape that reached the Illinois River and was exported. Nelson et al. (2002) found that 4% of P applied to the landscape in poultry litter, cattle manure, sludge and inorganic fertilizer was lost annually to the Illinois River. If cattle manure is removed from this, as the P contained in cattle manure is recycled P from other sources (poultry), this percentage is slightly over 5% which is comparable to the value reported by Sharpley et al. (2007) and by Willett et al. (2006).

Factors affecting the fate of phosphorus in a poultry farm.



Note: Numbers in parentheses are based on an approximate farm nutrient balance and relative fate of P as a percentage of load (farm gate) or percentage of fertilizer and manure (manure application and land management) (adapted from Howarth et al. 2000; Sims and Sharpley 2005).

Figure 8.1 Factors affecting P loss on poultry farms (From Sharpley et al. (2007))

Elevated soil P from poultry waste application to pasture can also contribute substantially to P losses in runoff. Figures 8.2 and 8.3 show the results of a study in which poultry litter was applied to Bermuda grass plots (Sharpley et al., 2007). The soil P levels increased, resulting in greatly increased surface runoff of P, even 6 years after litter application was stopped. For high levels of STP, P loss with runoff may occur for decades and beyond as highlighted in Section 10 of this report.

Daniels et al. (1999) indicate that areas with high soil test phosphorus levels can have appreciable amounts of soluble phosphorus in runoff water and significantly impact water quality in receiving streams and lakes.

A powerpoint presentation for Cargill producers indicates that the long term effects of poultry waste land application should not be overlooked (CARTP016287-CARTP016290).

Surface soil (0 to 5 cm) Mehlich-3 P and mean annual dissolved P concentration of surface runoff and subsurface flow (70 cm depth) from bermudagrass before, during, and after poultry litter application (11 Mg ha⁻¹ yr⁻¹; 140 kg P ha⁻¹ yr⁻¹).

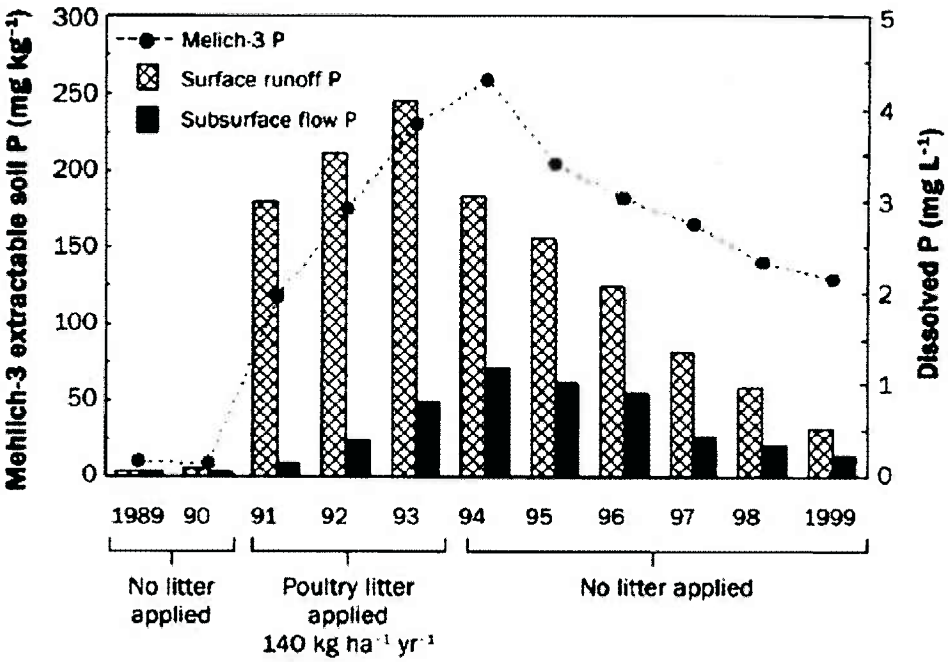


Figure 8.2. P Loads in Runoff Due to Elevated Soil P Levels (From Sharpley et al. (2007))

Phosphorus budget of poultry litter application, phosphorus uptake by bermudagrass, and total phosphorus loss in surface and subsurface flow from a Ruston fine sandy loam in Oklahoma.

Year	Litter P added (kg ha⁻¹ yr⁻¹)	Bermudagrass Yield (kg ha⁻¹ yr⁻¹)	Bermudagrass P uptake (kg ha⁻¹ yr⁻¹)	Total P loss in flow Surface (kg ha⁻¹ yr⁻¹)	Total P loss in flow Subsurface (kg ha⁻¹ yr⁻¹)	P balance
Before application						
1989	0	3,500	5.9	0.2	0.1	-6.2
1990	0	4,010	6.4	0.2	0.1	-6.7
During application						
1991	140	8,110	16.9	3.8	0.1	+119.2
1992	140	8,210	18.6	5.1	0.4	+115.9
1993	140	8,510	20.0	7.8	0.5	+111.7
After application						
1994	0	8,040	22.5	5.6	0.7	-28.8
1995	0	7,120	18.2	4.2	0.6	-23.0
1994	0	6,920	15.2	2.2	0.5	-15.9
1997	0	7,510	19.2	1.6	0.4	-21.2
1998	0	7,230	18.7	1.3	0.2	-20.2
1999	0	6,900	17.4	0.9	0.2	-18.5
Total	420	76,060	179.0	32.9	3.8	+206.0

Notes: Balance of P was determined as litter P added - P uptake by grass +P loss in surface runoff + P loss in subsurface flow. Negative values indicate a net loss of P from the plots and positive values a net gain of P.

Figure 8.3. P Loads in Runoff Due to Elevated Soil P Levels (From Sharpley et al. (2007))

Sharpley et al. (2007) indicate as soil test P increases, so does P in runoff (Figure 8.4).

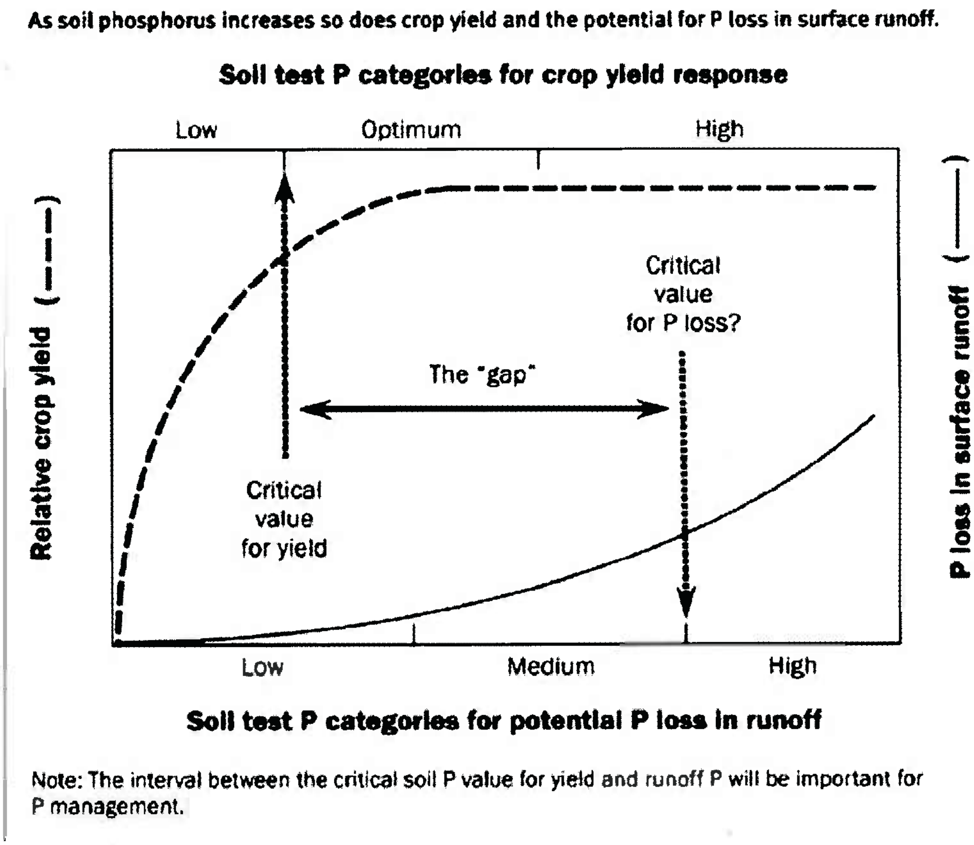


Figure 8.4. Relationship Between Soil Test P and P Loss in Surface Runoff (From Sharpley et al. (2007))

8.2 P Loads to IRW Water Based on Landscape Application and Literature P Loss Estimates

The P loads to water from NPS sources can be calculated based on the mass of P applied to the landscape annually and a coefficient (Sharpley et al., 2007; Willett et al., 2006; and Nelson et al., 2002). These authors all suggest the coefficient should be approximately 5% of P applied to the landscape. Using a coefficient of 5% and the defendants' poultry waste P content, the P losses from this poultry waste are shown in Table 8.1.

Table 8.1 Poultry P Loads in the IRW Based on Defendant Supplied Poultry Production Data and a 5% P Load Coefficient

Year	Total P (lbs)	Poultry P Load to Water (lbs)
2001	8,639,766	431,988
2002	8,702,182	435,109
2003	8,737,112	436,856
2004	9,975,305	498,765
2005	9,819,383	490,969
2006	9,000,113	450,006

As noted above, we computed a P mass balance for the IRW. The sources and amounts of P applied to the IRW crop and pasture land in 2002 are shown in Table 8.2. Based on these P applications to the landscape and a 5% loss to water, the total average annual P load in IRW water from these sources is approximately 570,000 lbs annually, with poultry waste responsible for more than 464,000 lbs annually. This is similar to the P load to water computed in Table 8.1. Poultry waste application to the landscape of the IRW results in substantial P loads to IRW waters and Lake Tenkiller.

Table 8.2. P Applied to the IRW Landscape in 2002

Source	**P (tons)**
Commercial Fertilizer	455
Poultry	4642
Swine	177
Dairy Cattle	319
Beef Cattle	105

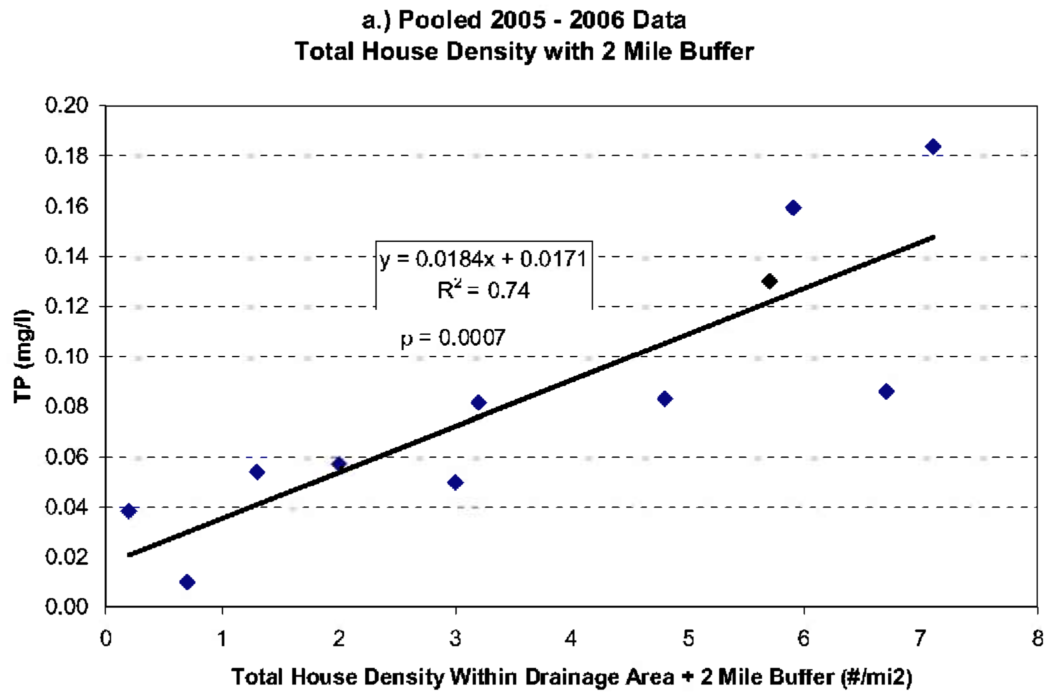
9. Poultry House Density Correlated to Elevated P Levels in Runoff and Base Flow

The analyses of observed P in runoff and in baseflow for 14 small watersheds within the Illinois River Watershed that were sampled in 2005 and 2006 show a strong and statistically significant correlation between P in runoff and in baseflow and poultry house density. Sub-basin poultry house densities are strong predictors of stream total phosphorus concentration showing a cause and effect relationship between poultry house operations and phosphorus concentrations in IRW waters. From these analyses, it is evident that poultry waste is a substantial contributor to P in stream runoff and in the baseflow within streams of the Illinois River Watershed.

Data were collected as part of the small tributary sampling program in the IRW (Olsen, 2008). Data were collected for both highflow and baseflow conditions throughout two summer periods (2005 and 2006). Data were collected from a total of fourteen sampling locations in small tributaries throughout the basin that covered a range of drainage area size and landuse characteristics. A representative range of poultry house presence (from no presence to highly active presence) was included in the sampling program. Further details of this sampling program are provided in Olsen (2008). Regression analyses were performed for measured total phosphorus concentrations as a function of a range of hypothesized potential predictor variables, including poultry house densities in and near the sampled watersheds.

As the following analysis demonstrates, sub-basin poultry house densities, in a variety of forms, are strong predictors of stream total phosphorus concentration showing a cause and effect relationship between poultry house operations and phosphorus concentrations in IRW waters. For the combined 2005-06 data sets, all 6 of the poultry house density predictor variable forms are shown to be significantly and positively correlated with total phosphorus concentrations in the receiving streams during highflow events. The strongest and most convincing correlations appear to be for the pooled 2005 – 06 phosphorus concentrations vs. total and active poultry house densities within a 2 mile buffered drainage area (see Appendix C). These results indicate that poultry house density is a good predictor of P concentration in runoff from sub-basins within the IRW. This finding is consistent with: (1) the observation that land application of poultry waste occurs near poultry houses (Section 4), (2) the fact that land disposal of poultry waste results in P loss in runoff, and (3) the fact that land disposal of poultry waste increases soil concentrations of P which also increases the amount of P in runoff water and which will elevate P levels in runoff water even after poultry waste disposal has stopped. Further details of the analysis are provided in Appendix C.

Figures 9.1 and 9.2 show the relationships between poultry house density within sub-basins (a. total and b. active) and a two mile buffer for runoff events and at baseflow, respectively. Significant relationships exist in each instance.



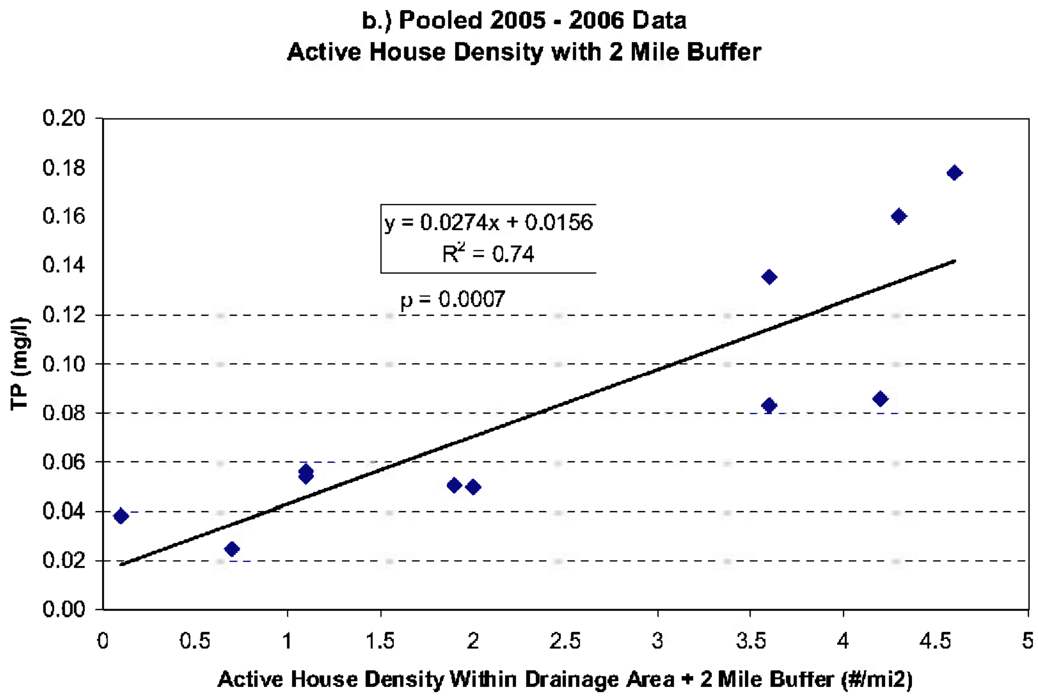
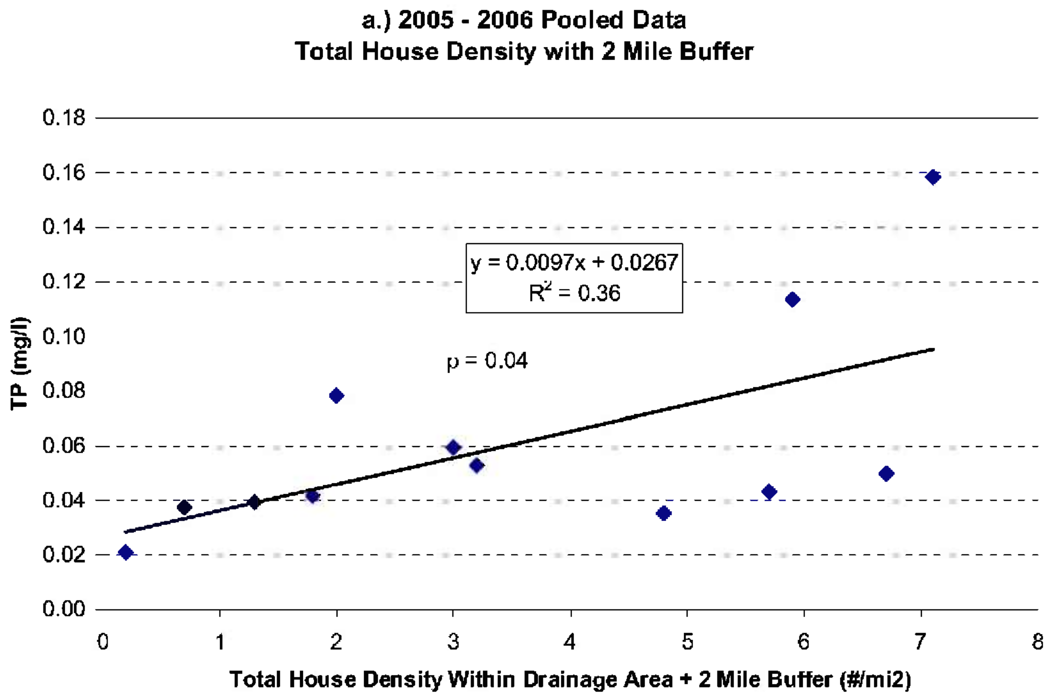


Figure 9.1 Runoff Event Regressions: Total Phosphorus Concentration vs. Poultry Presence



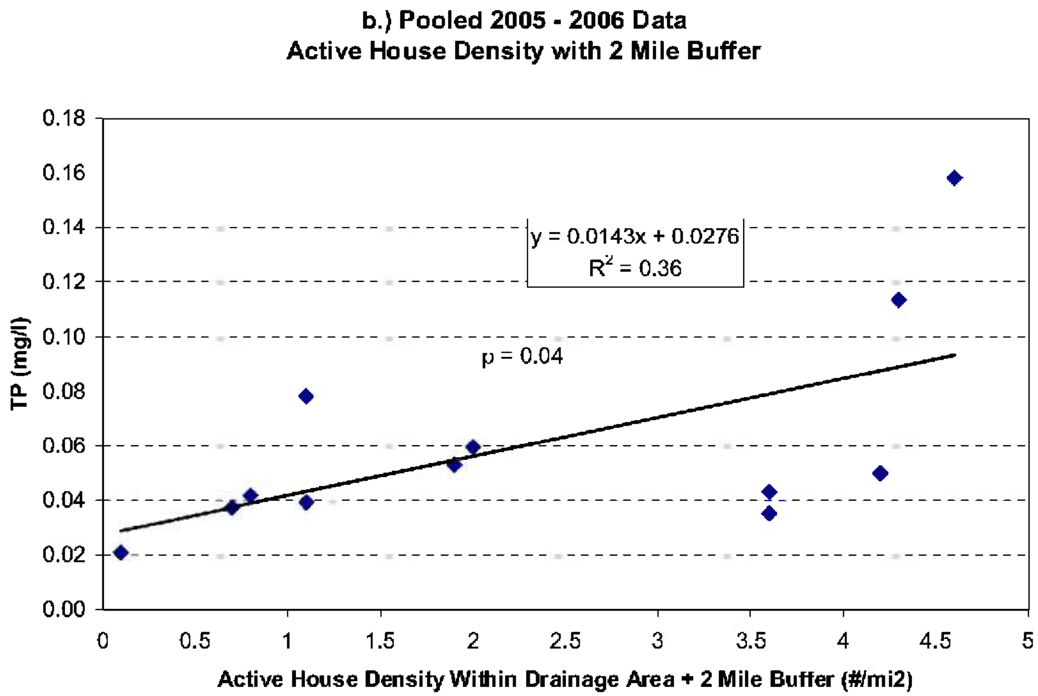


Figure 9.2. Baseflow Regressions: Total Phosphorus Concentration vs. Poultry Presence

Storm (2008) also analyzed P concentration in runoff and in baseflow from various sources for the Illinois River Watershed. Significant relationships were found between poultry house density and P in water (Figure 9.3). Relationships between urban/developed area and P in water were not significant (Figure 9.4).

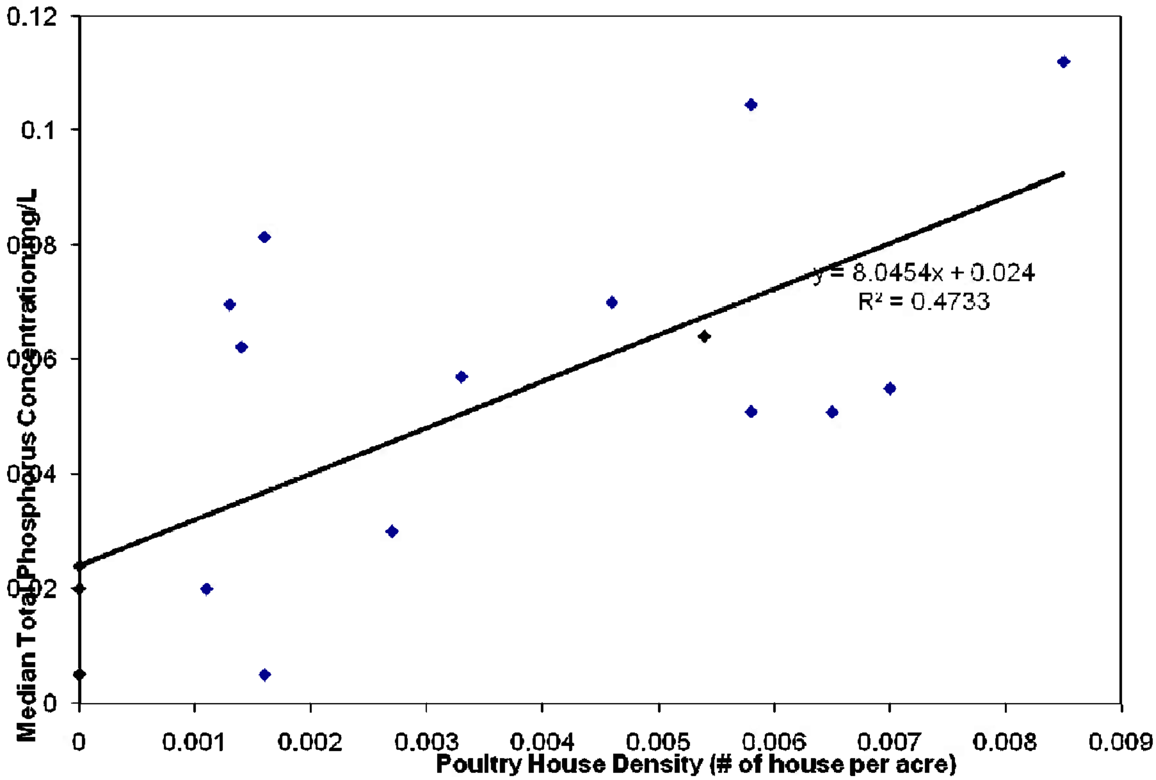


Figure 9.3. Relationship between poultry house density within a sub-basin and P concentration in water within the IRW (From Dr. Dan Storm, 2008)

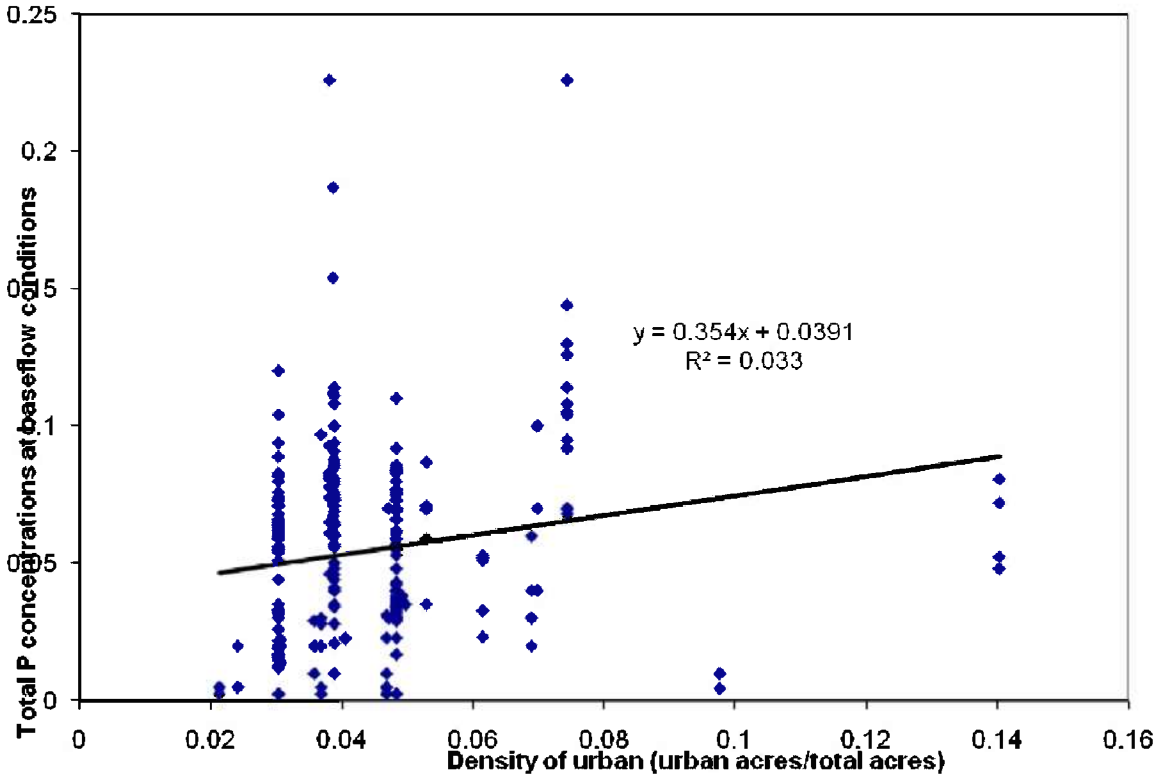


Figure 9 4. Relationship between amount of urban area and total P concentrations in water within the IRW (From Dr. Dan Storm, 2008)